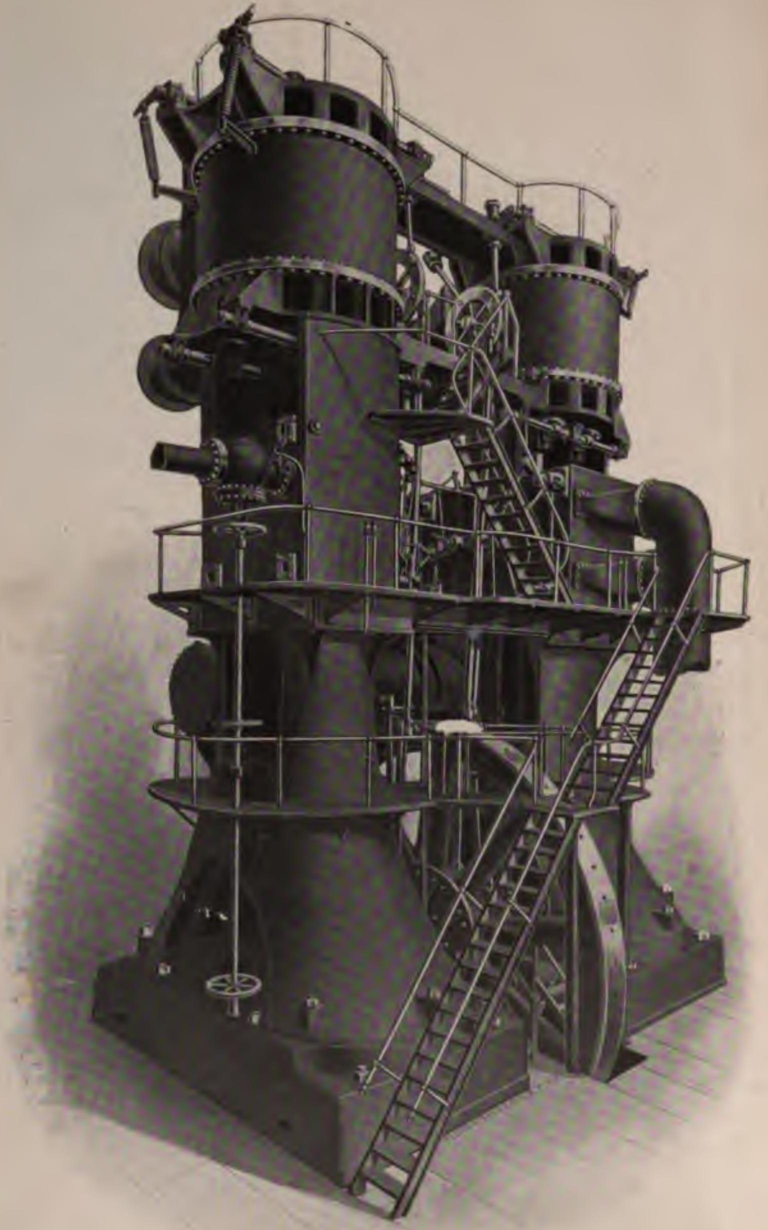

**BLOWING ENGINE.**
Steam Cylinder 58 × 108 × 60 inches. Air Cylinders 108 inches diameter.
Total Weight of Engine 1,270,000 Pounds.
William Tod Company.

# CYCLOPEDIA

OF

# Modern Shop Practice

*A Manual of*

SHOP PRACTICE, PATTERN MAKING, MACHINE DESIGN, FOUNDRY AND MACHINE SHOP WORK, FORGING, TOOL MAKING, SHEET METAL WORK, STEAM, REFRIGERATION, ELECTRICITY, ETC.

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DEAN, ARMOUR INSTITUTE OF TECHNOLOGY

*Assisted by a Corps of*

SHOP EXPERTS, DESIGNERS AND ENGINEERS

*Illustrated with over Two Thousand Engravings*

PART III

CHICAGO

AMERICAN TECHNICAL SOCIETY

1904

# Authorities Consulted.

In the preparation of these volumes the editors have received invaluable assistance from the foremost engineering firms and manufacturers. Grateful acknowledgment is here made for the valuable drawings, data, suggestions and criticisms which have enabled the editors to make these volumes representative of the latest and best practice in Mechanical Drawing and the Design and Construction of Machinery and Machine Tools.

The standard technical literature of Europe and America has been freely consulted in the preparation of these volumes. The editors desire to express their indebtedness, particularly to the following eminent authorities, whose well-known treatises should be in the library of every Mechanic and Engineer.

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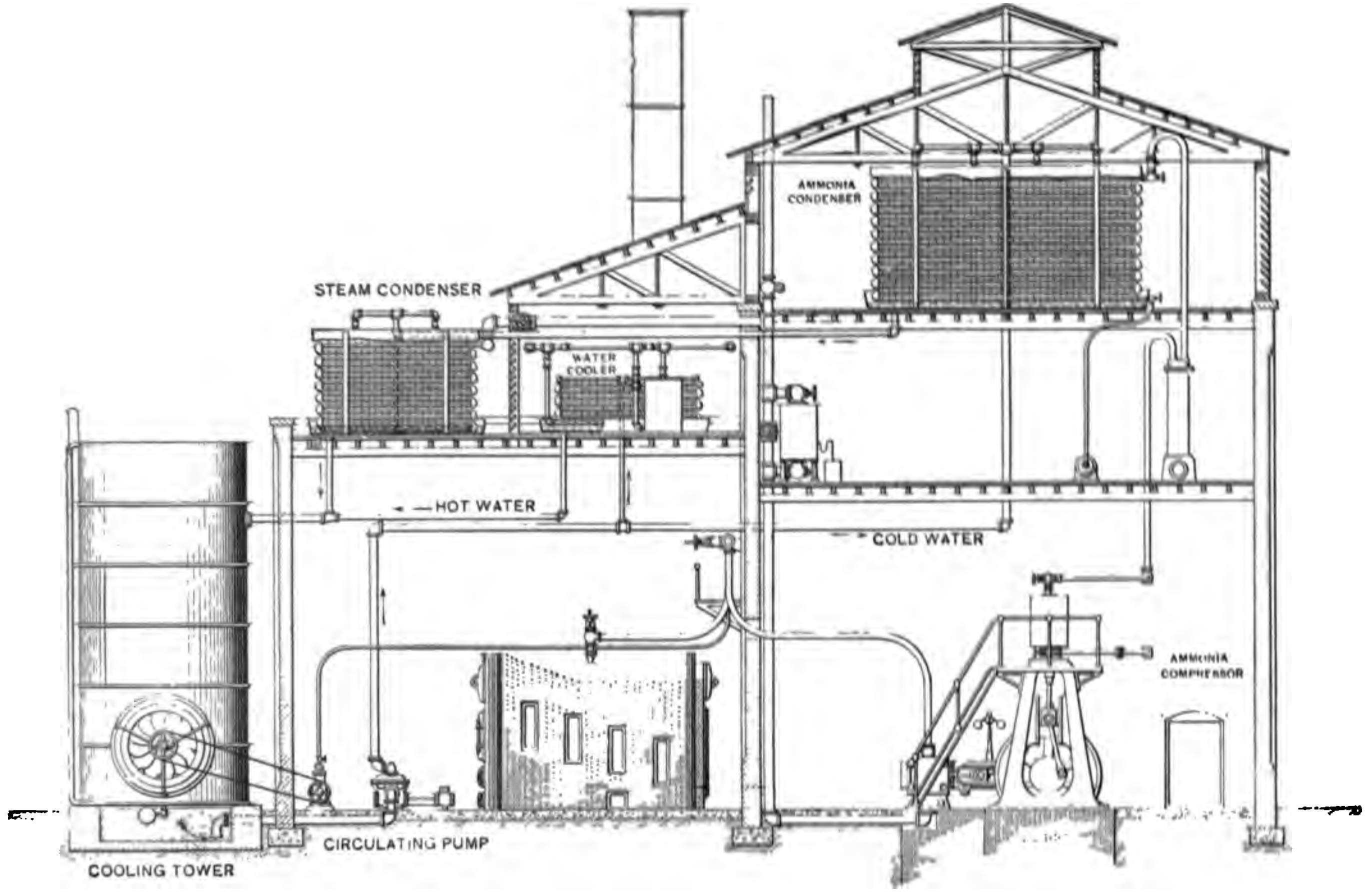
# Introductory Note.

THE successful education of the man in the shop is a question of vital importance. The difficulties under which he toils in his struggle for advancement, and his daily labor, render impossible the usual means of education, and prevent the attending of a resident technical school. Probably the most successful substitute for such a school is the correspondence method of instruction. Thousands of mechanics are improving their conditions by devoting a half hour each day in systematic study under the direction of men who have had long experience in teaching, and in practical shop work. There are, however, many who cannot afford the time and expense necessary for even a correspondence school course. For such the Cyclopedia of Modern Shop Practice is prepared.

¶ This Cyclopedia is compiled from the most practical and most valuable Instruction Papers of the American School of Correspondence. These Instruction Papers have been prepared especially for home study and are intended primarily for such work. As their extended use in the American School of Correspondence has proved them to be of great practical value, and a successful means of instruction, they form a reliable treatise on the subject of shop practice.

¶ The correspondence student needs a thoroughly technical work free from superfluous theory; in like manner the reader of the Cyclopedia must have the necessary theories carefully explained, and the results of practical experience clearly pointed out. By giving the best material on shop practice to the busy man in the shop, the editors hope that he will achieve the success that results from a combined knowledge of theory and practice.




**COOLING TOWER IN ICE MANUFACTURING PLANT.**
Alberger Condenser Company.

# MECHANICAL DRAWING.

The subject of mechanical drawing is of great interest and importance to all mechanics and engineers. Drawing is the method used to show graphically the small details of machinery; it is the language by which the designer speaks to the workman; it is the most graphical way to place ideas and calculations on record. Working drawings take the place of lengthy explanations, either written or verbal. A brief inspection of an accurate, well-executed drawing gives a better idea of a machine than a large amount of verbal description. The better and more clearly a drawing is made, the more intelligently the workman can comprehend the ideas of the designer. A thorough training in this important subject is necessary to the success of everyone engaged in mechanical work. The success of a draftsman depends to some extent upon the quality of his instruments and materials. Beginners frequently purchase a cheap grade of instruments. After they have become expert and have learned to take care of their instruments they discard them for those of better construction and finish. This plan has its advantages, but to do the best work, strong, well-made and finely finished instruments are necessary.

## INSTRUMENTS AND MATERIALS.

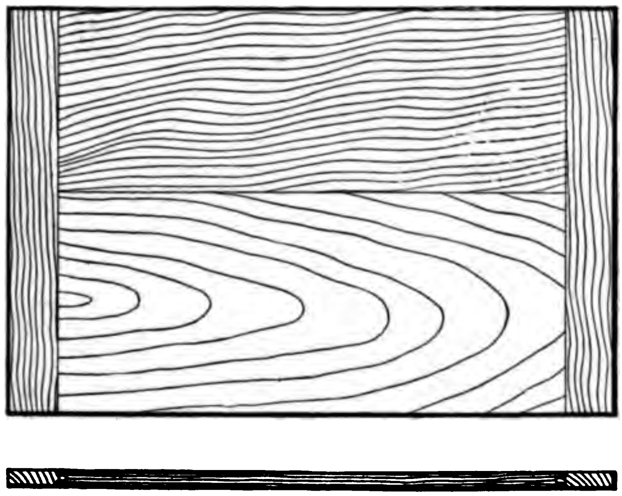
**Drawing Paper.** In selecting drawing paper, the first thing to be considered is the kind of paper most suitable for the proposed work. For shop drawings, a manilla paper is frequently used, on account of its toughness and strength, because the drawing is likely to be subjected to considerable hard usage. If a finished drawing is to be made, the best white drawing paper should be obtained, so that the drawing will not fade or become discolored with age. A good drawing paper should be strong, have uniform thickness and surface, should stretch evenly, and should neither repel nor absorb liquids. It should also allow considerable erasing without spoiling the surface, and it should lie smooth when stretched or when ink or colors are used. It is, of course, impossible to find all of these qualities in any one paper, as for instance great strength cannot be combined with fine surface.

In selecting a drawing paper the kind should be chosen which combines the greatest number of these qualities for the given work. Of the better class Whatman's are considered by far the best. This paper is made in three grades; the *hot pressed* has a smooth surface and is especially adapted for pencil and very fine line drawing, the *cold pressed* is rougher than the hot pressed, has a finely grained surface and is more suitable for water color drawing; the *rough* is used for tinting. The cold pressed does not take ink as well as the hot pressed, but erasures do not show as much on it, and it is better for general work. There is but little difference in the two sides of Whatman's paper, and either can be used. This paper comes in sheets of standard sizes as follows:—

| | | | |
|---|---|---|---|
| Cap, | 13 × 17 inches. | Elephant, | 23 × 28 inches. |
| Demy, | 15 × 20 " | Columbia, | 23 × 34 " |
| Medium, | 17 × 22 " | Atlas, | 26 × 34 " |
| Royal, | 19 × 24 " | Double Elephant, | 27 × 40 " |
| Super-Royal, | 19 × 27 " | Antiquarian, | 31 × 53 " |
| Imperial, | 22 × 30 " | Emperor, | 48 × 68 " |

The usual method of fastening paper to a drawing board is by means of thumb tacks or small one-ounce copper or iron tacks. In fastening the paper by this method first fasten the upper left hand corner and then the lower right pulling the paper taut. The other two corners are then fastened, and sufficient number of tacks are placed along the edges to make the paper lie smoothly. For very fine work the paper is usually stretched and glued to the board. To do this the edges of the paper are first turned up all the way round, the margin being at least one inch. The whole surface of the paper included between these turned up edges is then moistened by means of a sponge or soft cloth and paste or glue is spread on the turned up edges. After removing all the surplus water on the paper, the edges are pressed down on the board, commencing at one corner. During this process of laying down the edges, the paper should be stretched slightly by pulling the edges towards the edges of the drawing board. The drawing board is then placed horizontally and left to dry. After the paper has become dry it will be found to be as smooth and tight as a drum head. If, in stretching, the paper is stretched too much it is likely to split in drying. A slight stretch is sufficient.

**Drawing Board.** The size of the drawing board depends upon the size of paper. Many draftsmen, however, have several boards of various sizes, as they are very convenient. The drawing board is usually made of soft pine, which should be well seasoned and straight grained. The grain should run lengthwise of the board, and at the two ends there should be pieces about $1\frac{3}{4}$ or 2 inches wide fastened to the board by nails or screws. These end pieces should be perfectly straight for accuracy in using the T-square. Frequently the end pieces are fastened by a glued



DRAWING BOARD.

matched joint, nails and screws being also used. Two cleats on the bottom extending the whole width of the board, will reduce the tendency to warp, and make the board easier to move as they raise it from the table.

**Thumb Tacks.** Thumb tacks are used for fastening the paper to the drawing board. They are usually made of steel either pressed into shape, as in the cheaper grades, or made with a head of German silver with the point screwed and riveted to it. They are made in various sizes and are very convenient as they can be easily removed from the board. For most work however, draftsmen use small one-ounce copper or iron tacks, as they can be forced flush with the drawing paper, thus offering no obstruction to the T-square. They also possess the advantage of cheapness.

**Pencils.** In pencilling a drawing the lines should be very fine and light. To obtain these light lines a hard lead pencil must be used. Lead pencils are graded according to their hardness, and are numbered by using the letter H. In general a lead pencil of 5H (or HHHHH) or 6H should be used. A softer pencil, 4H, is better for making letters, figures and points. A hard lead pencil should be sharpened as shown in Fig. 1. The wood is cut away so that about $\frac{1}{4}$ or $\frac{3}{8}$ inch of lead projects. The lead can then be sharpened to a chisel edge by rubbing it against a bit of sand paper or a fine file. It should be ground to a chisel edge and the corners slightly rounded. In making the straight lines the chisel edge should be used by placing it against the T-square or triangle, and because of the chisel edge the lead will remain sharp much longer than if sharpened to a point. This chisel edge enables the draftsman to draw a fine line exactly through a given point. If the drawing is not to be inked, but is made for tracing or for rough usage in the shop, a softer pencil, 3H or 4H, may be used, as the lines will then be somewhat thicker and heavier. The lead for compasses may also be sharpened to a point although some draftsmen prefer to use a chisel edge in the compasses as well as for the pencil.

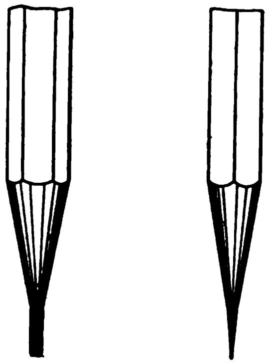


Fig. 1.

In using a very hard lead pencil, the chisel edge will make a deep depression in the paper if much pressure is put on the pencil. As this depression cannot be erased it is much better to press lightly on the pencil.

**Erasers.** In making drawings, but little erasing should be necessary. However, in case this is necessary, a soft rubber should be used. In erasing a line or letter, great care must be exercised or the surrounding work will also become erased. To prevent this, some draftsmen cut a slit about 3 inches long and $\frac{1}{8}$ to $\frac{1}{4}$ inch wide in a card as shown in Fig. 2. The card is then placed over the work and the line erased without erasing the rest of the drawing. An erasing shield of a form similar to that shown in Fig. 3 is very convenient, especially in erasing letters. It is made of thin sheet metal and is clean and durable.

For cleaning drawings, a sponge rubber may be used. Bread

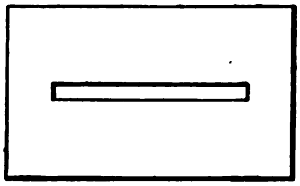


Fig. 2.

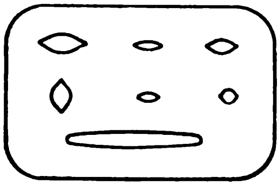


Fig. 3.

crumbs are also used for this purpose. To clean the drawing scatter *dry* bread crumbs over it and rub them on the surface with the hand.

**T-Square.** The T-square consists of a thin straight edge

Fig. 4.

called the blade, fastened to a head at right angles to it. It gets its name from the general shape. T-squares are made of various materials, wood being the most commonly used. Fig. 4 shows an ordinary form of T-square which is adapted to most work. In Fig. 5 is shown a T-square with edges made of ebony or mahogany, as these woods are much harder than pear wood or maple, which is generally used. The head is formed so as to fit against the left-hand edge of the drawing board, while the blade extends over the surface. It is desirable to have the blade of the T-square form a right angle with the head, so that the lines drawn with the T-square will be at right angles to the left-hand edge of the board. This, however, is not absolutely necessary, because the lines drawn with the T-square are always with reference to one edge of the board only, and if this edge of the board is straight, the lines drawn with the T-square will be parallel to each other. The T-square should never be used except with the left-hand edge of the board, as it is almost impossible to find a drawing broad with the edges parallel or at right angles to each other.

The T-square with an adjustable head is frequently very convenient, as it is sometimes necessary to draw lines parallel to each

Fig. 5.

other which are not at right angles to the left-hand edge of the board. This form of T-square is similar to the ordinary T-square already described, but the head is swiveled so that it may be clamped at any desired angle. The ordinary T-square as shown in Figs. 4 and 5 is, however, adapted to almost any class of drawing.

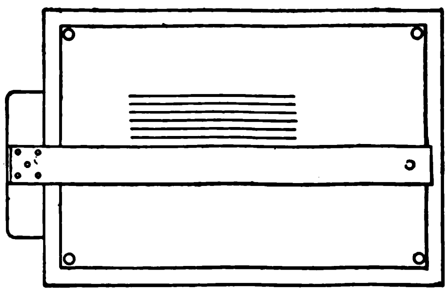


Fig. 6.

Fig. 6 shows the method of drawing parallel horizontal lines with the T-square. With the head of the T-square in contact with the left-hand edge of the board, the lines may be drawn by moving the T-square to the desired position. In using the T-square the upper edge should always be used for drawing as the two edges may not be exactly parallel and straight, and also it is more convenient to use this edge with the triangles. If it is necessary to use a straight edge for trimming drawings or cutting the paper from the board, the lower edge of the T-square should be used so that the upper edge may not be marred.

For accurate work it is absolutely necessary that the working edge of the T-square should be exactly straight. To test the straightness of the edge of the T-square, two T-squares may be placed together as shown in Fig. 7. This figure shows plainly that the edge of one of the T-squares is crooked. This fact, however, does not prove that either one is straight, and for this determination a third blade must be used and tried with the two given T-squares successively.

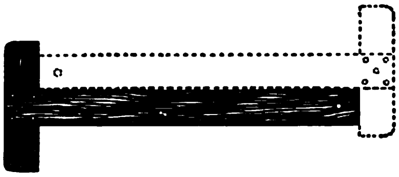
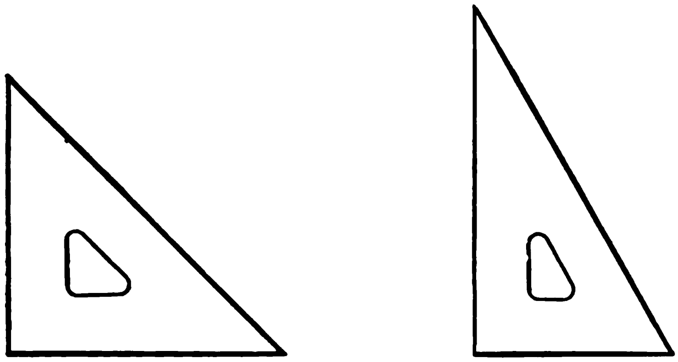


Fig. 7.

**Triangles.** Triangles are made of various substances such as wood, rubber, celluloid and steel. Wooden triangles are cheap but are likely to warp and get out of shape. The rubber triangles are frequently used, and are in general satisfactory. The transparent celluloid triangle is, however, extensively used on account of its transparency, which enables the draftsmen to see the work already done even when covered with the triangle. In using a rubber or celluloid triangle take care that it lies perfectly flat or



TRIANGLES.

is hung up when not in use; when allowed to lie on the drawing board with a pencil or an eraser under one corner it will become warped in a short time, especially if the room is hot or the sun happens to strike the triangle.

Triangles are made in various sizes, and many draftsmen have several constantly on hand. A triangle from 6 to 8 inches on a side will be found convenient for most work, although there are many cases where a small triangle measuring about 4 inches on a side will be found useful. Two triangles are necessary for every draftsman, one having two angles of 45 degrees each and one a right angle; and the other having one angle of 60 degrees, one of 30 degrees and one of 90 degrees.

The value of the triangle depends upon the accuracy of the angles and the straightness of the edges. To test the accuracy of the right angle of a triangle, place the triangle with the lower edge resting on the edge of the T-square, as shown in Fig. 8. Now draw the line C D, which should be perpendicular to the edge of the T-square. The same triangle should then be placed in the position shown at B. If the right angle of the triangle is exactly 90 degrees the left-hand edge of the triangle should exactly coincide with the line C D.

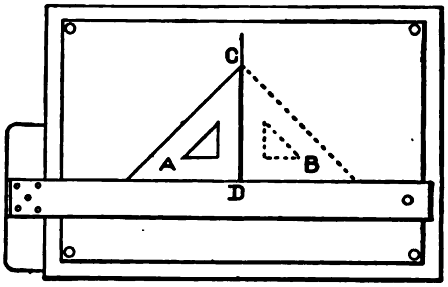


Fig. 8.

To test the accuracy of the 45-degree triangles, first test the right angle then place the triangle with the lower edge resting on the working edge of the T-square, and draw the line E F as shown in Fig. 9. Now without moving the T-square place the triangle so that the other 45-degree angle is in the position occupied by the first. If the two 45-degree angles coincide they are accurate.

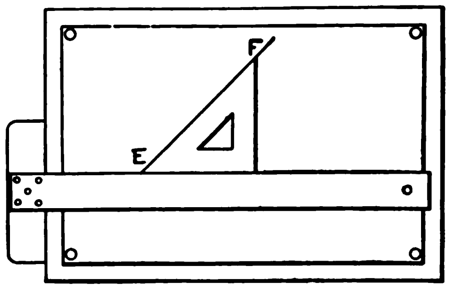


Fig. 9.

Triangles are very convenient in drawing lines at right angles to the T-square. The method of doing this is shown in Fig. 10. Triangles are also used in drawing lines at an angle with the horizontal, by placing them on the board as shown in Fig. 11. Suppose the line E F (Fig. 12) is drawn at any angle, and we wish to draw a line through the point P parallel to it.

First place one of the triangles as shown at A, having one edge coinciding with the given line. Now take the other triangle and place one of its edges in contact with the bottom edge of triangle A. Holding the triangle B firmly with the left hand the triangle A may be slipped along to the right or to the left until the edge of the triangle reaches the point P. The line M N may then be drawn along the edge of the triangle passing through the point P. In place of the triangle B any straight edge such as a T-square may be used.

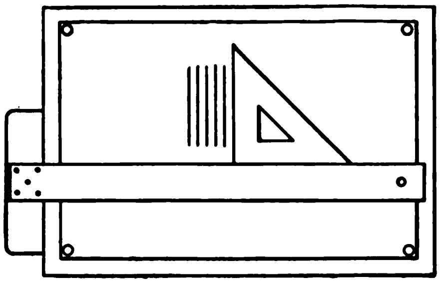


Fig. 10.

A line can be drawn perpendicular to another by means of the triangles as follows. Let E F (Fig. 13) be the given line, and suppose we wish to draw a line perpendicular to E F through the point D. Place the longest side of one of the triangles so that it coincides with the line E F, as the triangle is shown in position at A. Place the other triangle (or any straight edge) in the position of the triangle as shown at B, one edge resting against the edge of the triangle A. Then holding B with the left hand, place the triangle A in the position shown at C, so that the longest side passes through the point D. A line can then be drawn through the point D perpendicular to E F.

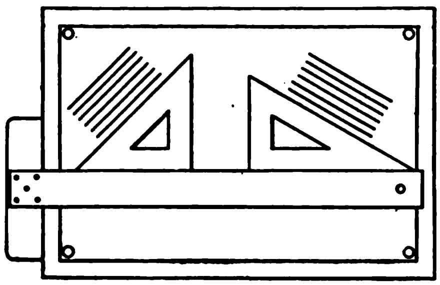


Fig. 11.

In previous figures we have seen how lines may be drawn making angles of 30, 45, 60 and 90 degrees with the horizontal. If it is desired to draw lines forming angles of 15 and 75 degrees the triangles may be placed as shown in Fig. 14.

In using the triangles and T-square almost any line may be drawn. Suppose we wish to draw a rectangle having one side horizontal. First place the T-square as shown in Fig. 15. By moving the T-square up or down, the sides A B and D C may be drawn, because they are horizontal and parallel. Now place one of the triangles resting on the T-square as shown at E, and having the left-hand edge passing through the point D. The vertical

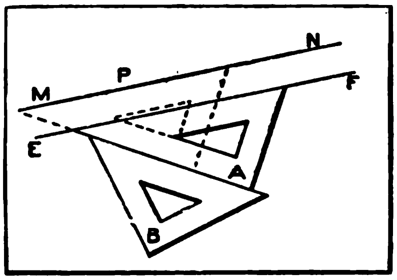



Fig. 12.

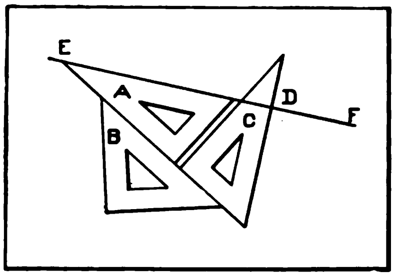



Fig. 13.

line D A may be drawn, and by sliding the triangle along the edge of the T-square to the position F the line B C may be drawn by using the same edge. These positions are shown dotted in Fig. 15.

If the rectangle is to be placed in some other position on the drawing board, as shown in Fig. 16, place the 45-degree triangle F so that one edge is parallel to or coincides with the side D C. Now holding the triangle F in position place the triangle H so that its upper edge coincides with the lower edge of the triangle F. By holding H in position and sliding the triangle F along its upper edge, the sides A B and D C may be drawn. To draw the sides A D and B C the triangle should be used as shown at E.

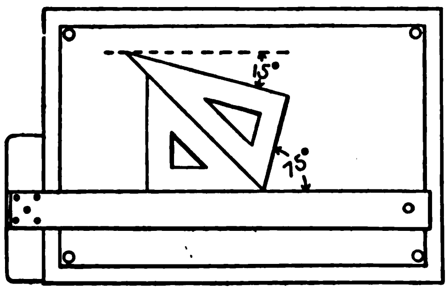



Fig. 14.

**Compasses.** Compasses are used for drawing circles and arcs of circles. They are made of various materials and in various sizes. The cheaper class of instruments are made of brass, but they are unsatisfactory on account of the odor and the tendency to tarnish. The best material is German silver. It does not soil readily, it has no odor, and is easy to keep clean. Aluminum instruments possess the advantage of lightness, but on account of the soft metal they do not wear well.

The compasses are made in the form shown in Figs. 17 and 18. Pencil and pen points are provided, as shown in Fig. 17. Either pen or pencil may be inserted in one leg by means of a shank and socket. The other leg is fitted with a needle point which is placed at the center of the circle. In most instruments the needle point is separate, and is made of a piece of round steel wire having a square shoulder at one or both ends. Below this shoulder the needle point projects. The needle is made in this form so that the hole in the paper may be very minute.

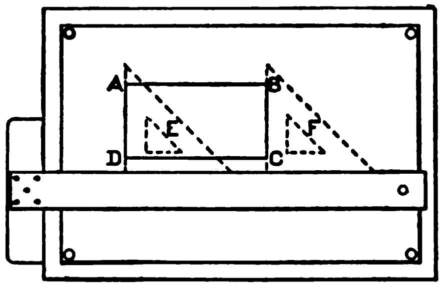


Fig. 15.

In some instruments lock nuts are used to hold the joint firmly in position. These lock nuts are thin discs of steel, with notches for using a wrench or forked key. Fig. 19 shows the detail of the joint of high grade instruments. Both legs are alike at the joint, and two pivoted screws are inserted in the yoke. This permits ample movement of the legs, and at the same time gives the proper stiffness. The flat surface of one of the legs is faced with steel, the other being of German silver, in order that the rubbing parts may be of different metals. Small set screws are used to prevent the pivoted screws from turning in the yoke. The contact surfaces of this joint are made circular to exclude dust and dirt and to prevent rusting of the steel face.

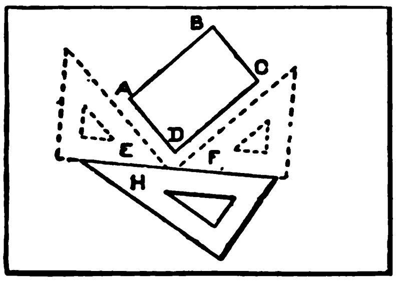


Fig. 16.

Figs. 20, 21, and 22 show the detail of the socket; in some instruments the shank and socket are pentagonal, as shown in Fig. 20. The shank enters the socket loosely, and is held in place by means of the screw. Unless used very carefully this arrangement is not durable because the sharp corners soon wear, and the pressure on the set screw is not sufficient to hold the shank firmly in place.

In Fig. 21 is shown another form of shank. This is round, having a flat top. A set screw is also used to hold this in position. A still better form of socket is shown in Fig. 22; the hole

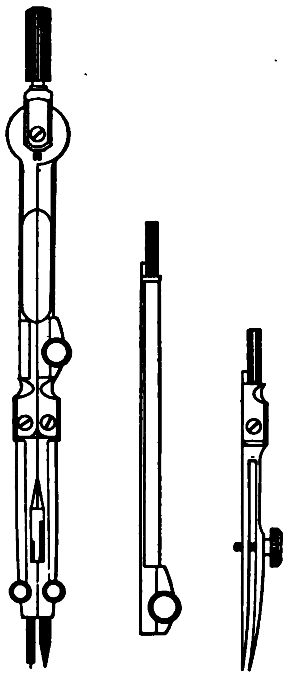


Fig. 17.

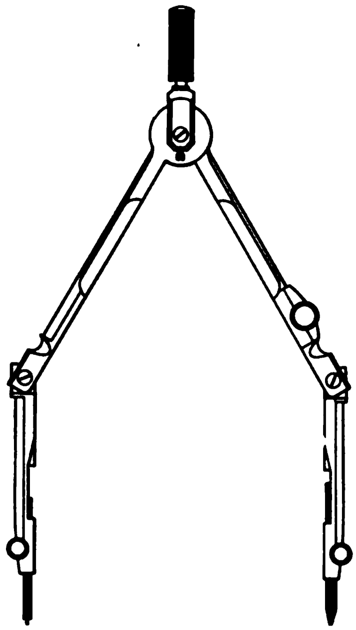


Fig. 18.

is made tapered and is circular. The shank fits accurately, and is held in perfect alignment by a small steel key. The clamping screw is placed upon the side, and keeps the two portions of the split socket together.

Figs. 17 and 18 show that both legs of the compasses are jointed in order that the lower part of the legs may be perpendicular to the paper while drawing circles. In this way the needle point makes but a small hole in the paper, and both nibs of the pen will press equally on the paper. In pencilling circles it is not as necessary that the pencil should be kept vertical; it is a good plan, however, to learn to use them in this way both in pencilling and inking. The compasses should be held loosely between the thumb and forefinger. If the needle point is sharp, as it should be, only a slight pressure will be required to keep it in place. While drawing the circle, incline the compasses slightly in the direction of revolution and press lightly on the pencil or pen.

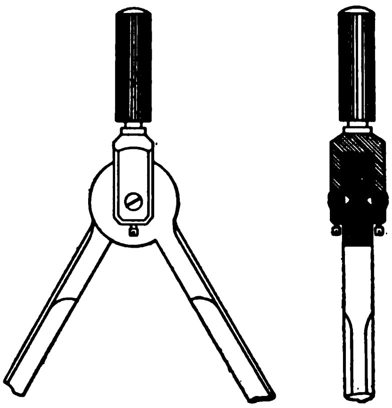


Fig. 19.

In removing the pencil or pen, it should be pulled out straight. If bent from side to side the socket will become enlarged and the shank worn; this will render the instrument inaccurate. For drawing large circles the lengthening bar shown in Fig. 17 should be used. When using the lengthening bar the

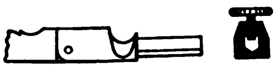


Fig. 20.

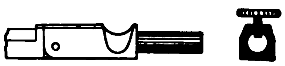


Fig. 21.

needle point should be steadied with one hand and the circle described with the other.

**Dividers.** Dividers, shown in Fig. 23, are made similar to the compasses. They are used for laying off distances on the drawing, either from scales or from other parts of the drawing. They may also be used for dividing a line into equal parts. When dividing a line into equal parts the dividers should be turned in the opposite direction each time, so that the moving point passes alternately to the right and to the left. The instrument can then be operated readily with one hand. The points of the dividers should be very sharp so that the holes made in the paper will be small. If large holes are made in the paper, and the distances between


Fig. 22.

the points are not exact, accurate spacing cannot be done Sometimes the compasses are furnished with steel divider points in addition to the pen and pencil points. The compasses may then be used either as dividers or as compasses. Many draftsmen use a *needle point* in place of dividers for making measurements from a scale. The eye end of a needle is first broken off and the needle then forced into a small handle made of a round piece of soft pine. This instrument is very convenient for indicating the intersection of lines and marking off distances.

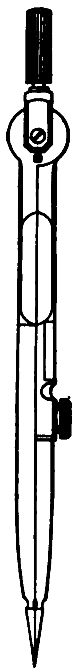


Fig. 23.

**Bow Pen and Bow Pencil.** Ordinary large compasses are too heavy to use in making small circles, fillets, etc. The leverage of the long leg is so great that it is very difficult to draw small circles accurately. For this reason the bow compasses shown in Figs. 24 and 25 should be used on all arcs and circles having a radius of less than three-quarters inch. The bow compasses are also convenient for duplicating small circles such as those which represent boiler tubes, bolt holes, etc., since there is no tendency to slip.

The needle point must be adjusted to the same length as the pen or pencil point if very small circles are to be drawn. The adjustment for altering the radius of the circle can be made by turning the nut. If the change in radius is considerable the points should be pressed together to remove the pressure from the nut which can then be turned in either direction with but little wear on the threads.

Fig. 26 shows another bow instrument which is frequently used in small work in place of the dividers. It has the advantage of retaining the adjustment.

**Drawing Pen.** For drawing straight lines and curves that are not arcs of circles, the line pen (sometimes called the ruling pen) is used. It consists of two blades of steel fastened to a handle as shown in Fig. 27. The distance between the pen points can be adjusted by the thumb screw, thus regulating the width of line to be drawn. The blades are given a slight curvature so that there will be a cavity for ink when the points are close together.

The pen may be filled by means of a common steel pen or with the quill which is provided with some liquid inks. The pen should not be dipped in the ink because it will then be necessary to wipe the outside of the blades before use. The ink should fill the pen to a height of about $\frac{1}{4}$ or $\frac{3}{8}$ inch; if too much ink is placed in the pen it is likely to drop out and spoil the drawing. Upon finishing the work the pen should be carefully wiped with

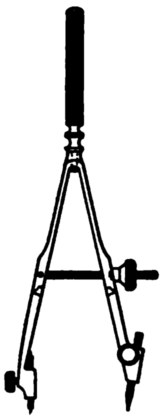


Fig. 24.

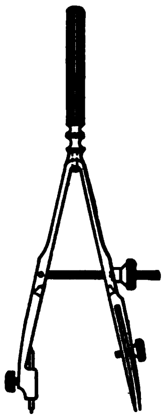


Fig. 25.

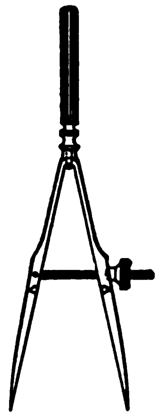


Fig. 26.

chamois or a soft cloth, because most liquid inks corrode the steel.

In using the pen, care should be taken that both blades bear equally on the paper. If the points do not bear equally the line will be ragged. If both points touch, and the pen is in good condition the line will be smooth. The pen is usually inclined slightly in the direction in which the line is drawn. The pen

Fig. 27.

should *touch* the triangle or T-square which serve as guides, but it should not be pressed against them because the lines will then be uneven. The points of the pen should be close to the edge of the triangle or T-square, but should not touch it.

*To Sharpen the Drawing Pen.* After the pen has been used for some time the points become worn, and it is impossible to make smooth lines. This is especially true if rough paper is used. The pen can be put in proper condition by sharpening it. To do this take a small, flat, close-grained oil-stone. The blades should first be screwed together, and the points of the pen can be given the proper shape by drawing the pen back and forth over the stone changing the inclination so that the shape of the ends will be parabolic. This process dulls the points but gives them the proper shape, and makes them of the same length.

To sharpen the pen, separate the points slightly and rub one of them on the oil-stone. While doing this keep the pen at an angle of from 10 to 15 degrees with the face of the stone, and give it a slight twisting movement. This part of the operation requires great care as the shape of the ends must not be altered. After the pen point has become fairly sharp the other point should be ground in the same manner. All the grinding should be done on the *outside* of the blades. The burr should be removed from the inside of the blades by using a piece of leather or a piece of pine wood.

Ink should now be placed between the blades and the pen tried. The pen should make a smooth line whether fine or heavy, but if it does not the grinding must be continued and the pen tried frequently.

**Ink.** India ink is always used for drawing as it makes a permanent black line. It may be purchased in solid stick form or as a liquid. The liquid form is very convenient as much time is saved, and all the lines will be of the same color; the acid in the ink, however, corrodes steel and makes it necessary to keep the pen perfectly clean.

Some draftsmen prefer to use the India ink which comes in stick form. To prepare it for use, a little water should be placed in a saucer and one end of the stick placed in it. The ink is ground by giving it a twisting movement. When the water has become black and slightly thickened, it should be tried. A heavy line should be made on a sheet of paper and allowed to dry. If the line has a grayish appearance, more grinding is necessary. After the ink is thick enough to make a good black line, the grinding should cease, because very thick ink will not flow freely from the pen. If, however, the ink has become too thick, it may be diluted with water. After using, the stick should be wiped dry to prevent crumbling. It is well to grind the ink in small quantities as it does not dissolve readily if it has once become dry. If the ink is kept covered it will keep for two or three days.

**Scales.** Scales are used for obtaining the various measurements on drawings. They are made in several forms, the most convenient being the flat with beveled edges and the triangular. The scale is usually a little over 12 inches long and is graduated for a distance of 12 inches. The triangular scale shown in Fig. 28 has six surfaces for graduations, thus allowing many graduations on the same scale.

The graduations on the scales are arranged so that the drawings may be made in any proportion to the actual size. For mechanical work, the common divisions are multiples of two.

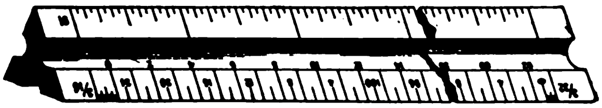


Fig. 28.

Thus we make drawings full size, half size, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, etc. If a drawing is $\frac{1}{4}$ size, 3 inches equals 1 foot, hence 3 inches is divided into 12 equal parts and each division represents one inch. If the smallest division on a scale represents $\frac{1}{16}$ inch, the scale is said to read to $\frac{1}{16}$ inch.

Scales are often divided into $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, etc., for architects, civil engineers, and for measuring on indicator cards.

The scale should never be used for drawing lines in place of triangles or T-square.

**Protractor.** The protractor is an instrument used for laying off and measuring angles. It is made of steel, brass, horn and paper. If made of metal the central portion is cut out as shown in Fig. 29, so that the draftsman can see the drawing. The outer edge is divided into degrees and tenths of degrees. Sometimes the graduations are very fine. In using a protractor a very sharp hard pencil should be used so that the lines will be fine and accurate.

The protractor should be placed so that the given line (produced if necessary) coincides with the two O marks. The center of the circle being placed at the point through which the desired line is to be drawn. The division can then be marked with the pencil point or needle point.

**Irregular Curve.** One of the conveniences of a draftsman's

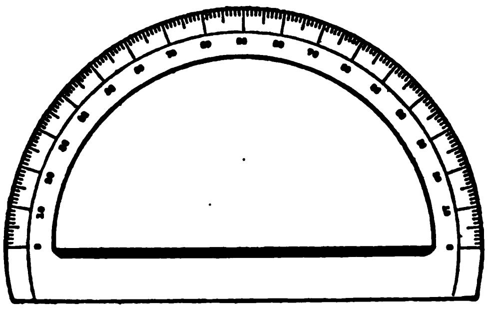


Fig. 29.

outfit is the French or irregular curve. It is made of wood, hard rubber or celluloid, the last named material being the best. It is made in various shapes, two of the most common being

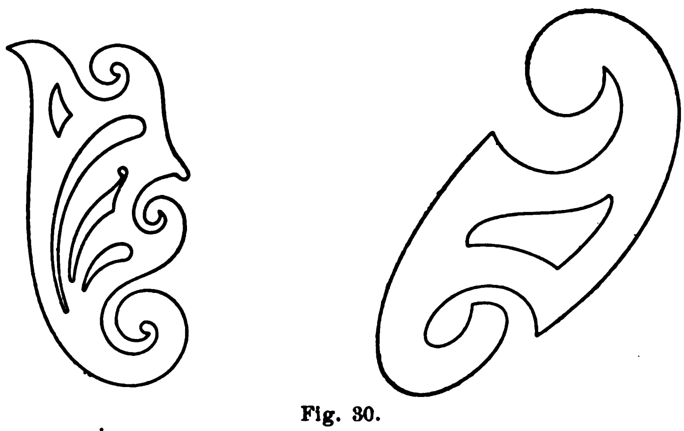


Fig. 30.

shown in Fig. 30. This instrument is used for drawing curves other than arcs of circles, and both pencil and line pen can be used.

To draw the curve, a series of points is first located and then the curve drawn passing through them by using the part of the irregular curve that passes through several of them. The curve is shifted for this work from one position to another. It frequently facilitates the work and improves its appearance to draw a free hand pencil curve through the points and then use the irregular curve, taking care that it always fits at least *three* points.

In inking the curve, the blades of the pen must be kept

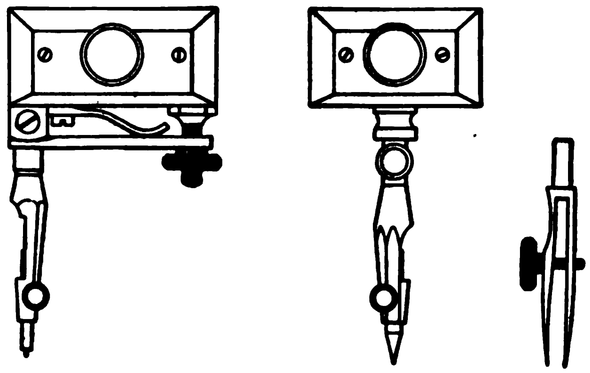


Fig. 31.

tangent to the curve, thus necessitating a continual change of direction.

**Beam Compasses.** The ordinary compasses are not large enough to draw circles having a diameter greater than about 8 or 10 inches. A convenient instrument for larger circles is found in the beam compasses shown in Fig. 31. The two parts called channels carrying the pen or pencil and the needle point are clamped to a wooden beam; the distance between them being equal to the radius of the circle. Accurate adjustment is obtained by means of a thumb nut underneath one of the channel pieces.

## PLATES.

Plates I, II and III are provided to give practice in the use of the drawing instruments. Drawing paper at least 11 inches by 15 inches should be used to allow border lines 10 inches by 14 inches. First, draw carefully in pencil and then ink in. Especial care should be taken as to quality and width of line, intersections, and the joining of curved and straight lines.

These are followed by examples for lettering. Plate IV sho be drawn first in pencil and then in ink.

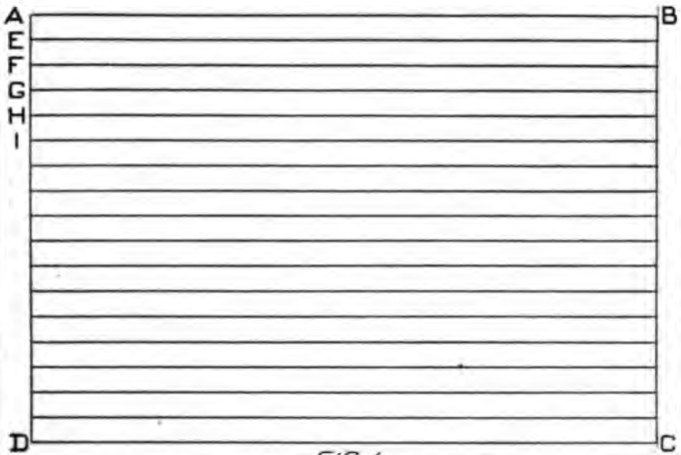



FIG. 1

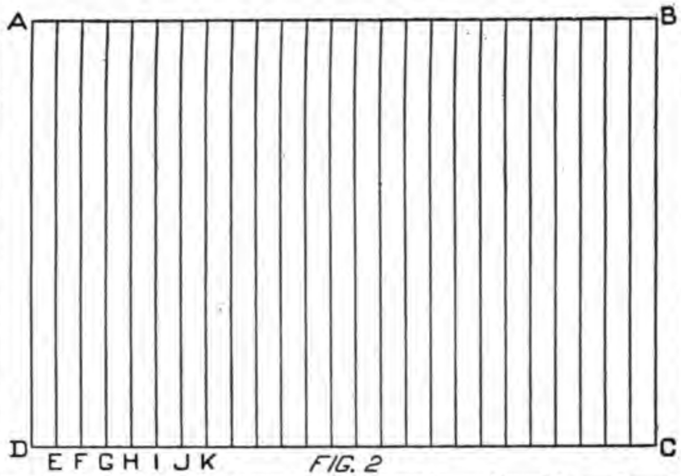



FIG. 2

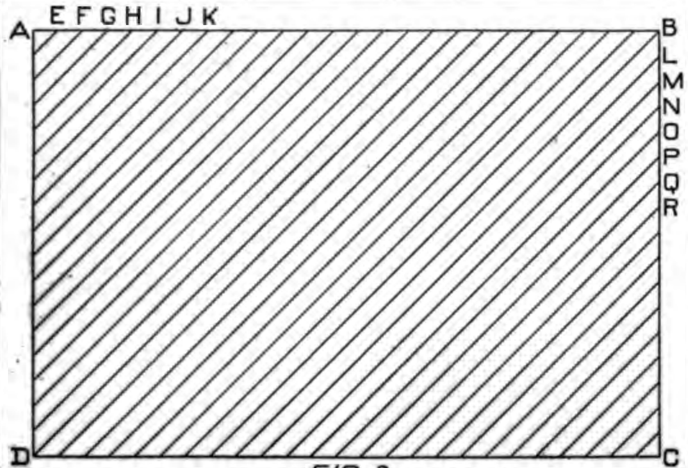



FIG. 3

A B C D

LETTERING

THE SUBJECT OF LETTERING IS OF GREAT IMPORTANCE TO THE MECHANICAL DRAUGHTSMAN. MANY WELL EXECUTED DRAWINGS HAVE BEEN DISFIGURED BY POOR LETTERING.

*Proficiency can be acquired only by practice. Practice lettering. Practice.*

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

1234567890

I II III IV V VI VII VIII IX X

FIG. 4

PLATE II

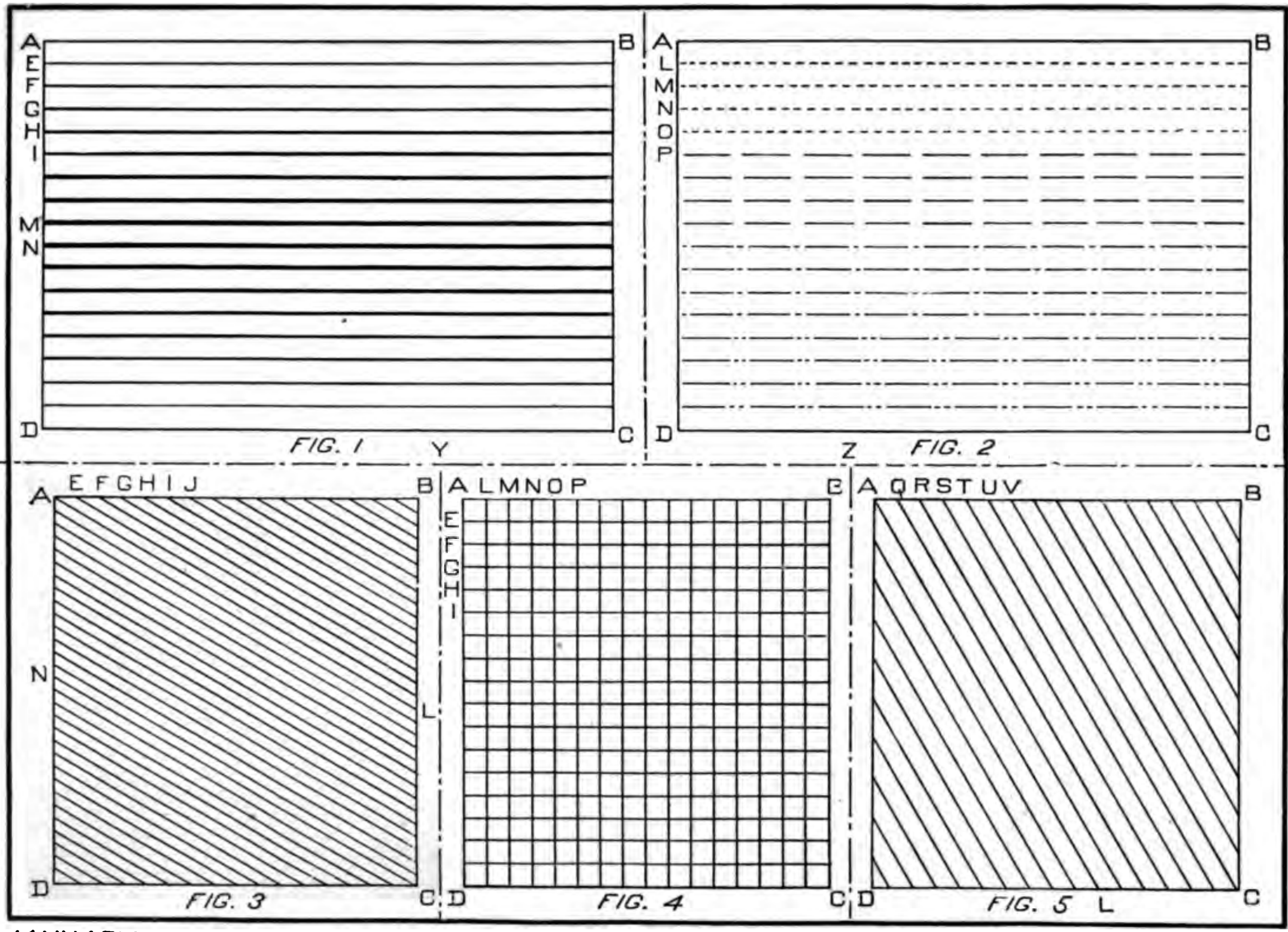



FIG. 1 FIG. 2 FIG. 3 FIG. 4 FIG. 5

PLATE III

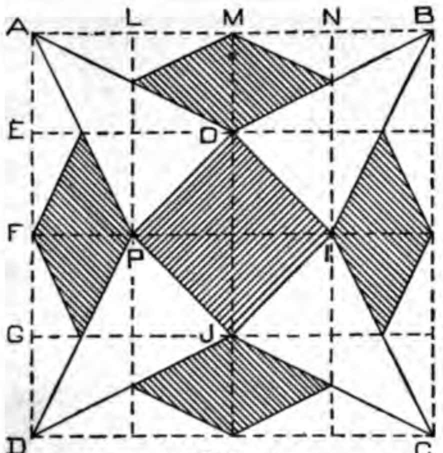



FIG 1

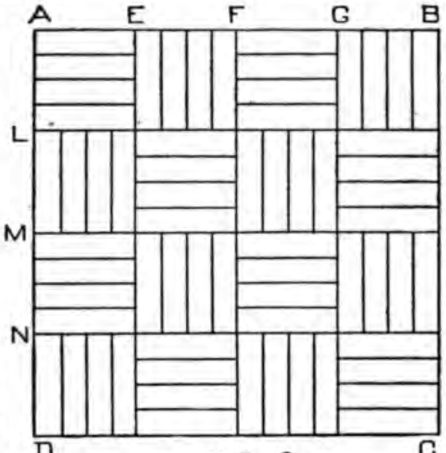



FIG. 2

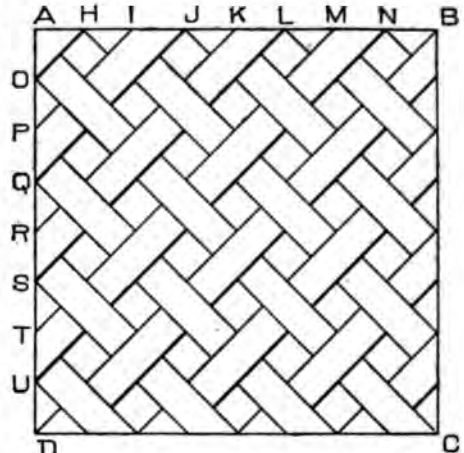



FIG. 3

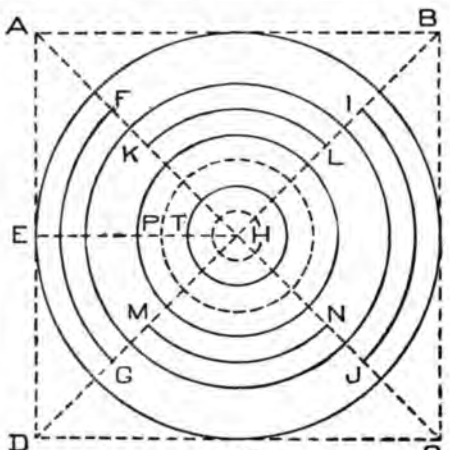



FIG. 4

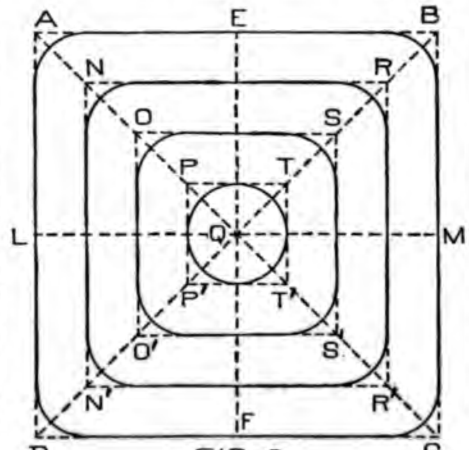



FIG. 5

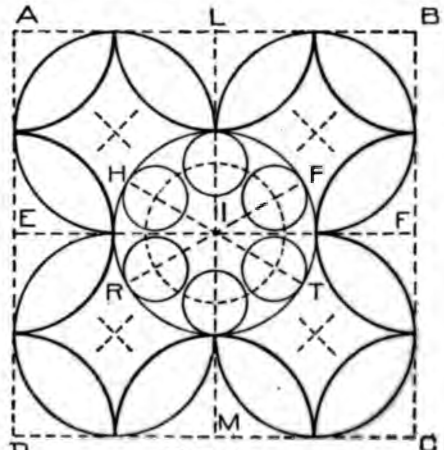



FIG. 6

# COURSE

IN

MECHANICAL DRAWING

# MACHINE DRAWINGS

AND

# PROJECTIONS

*BOSTON, MASS., U.S.A.*

*1901*

APRIL 24. 1901 HERBERT CHANDLER CHICAGO. ILL

PLATE III

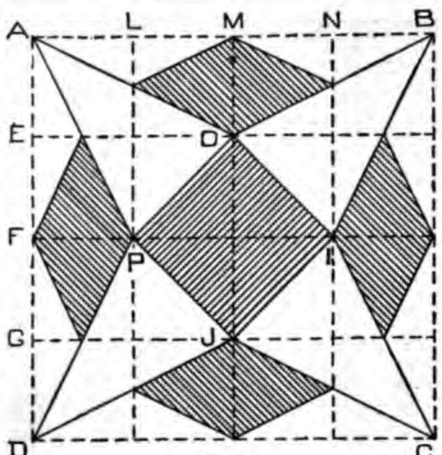



FIG 1

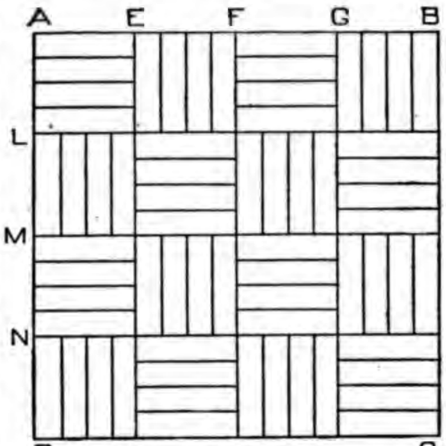



FIG. 2

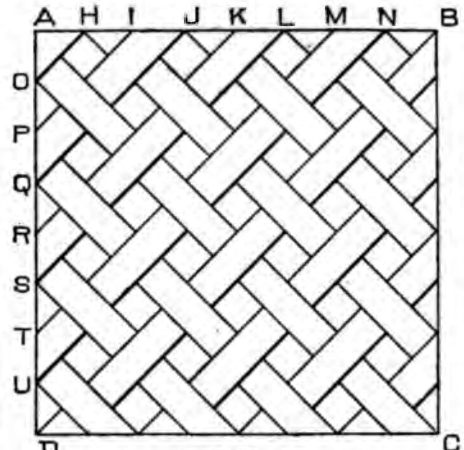



FIG. 3

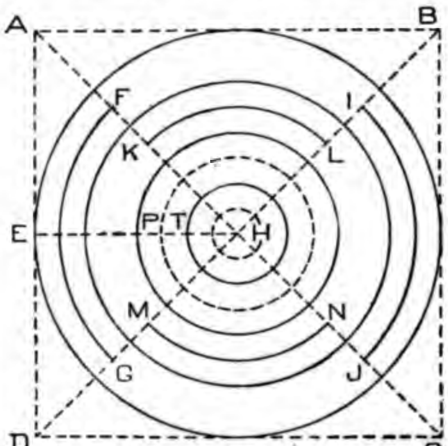



FIG. 4

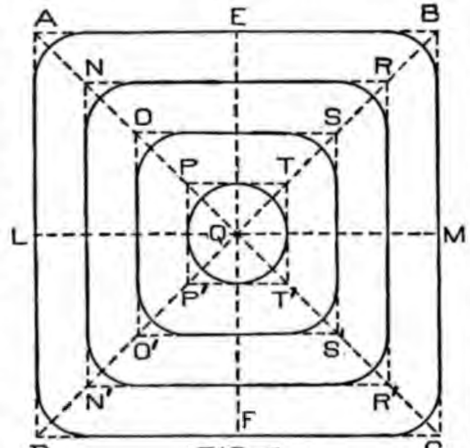



FIG. 5

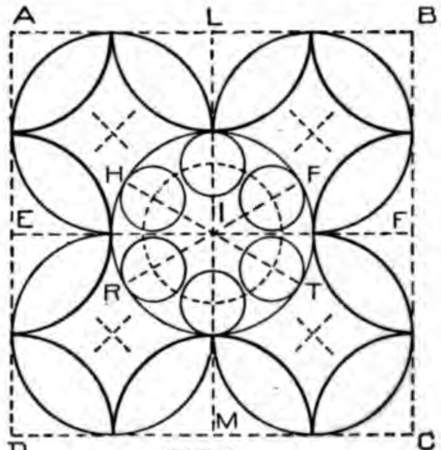



FIG. 6

PLATE IV

COURSE

IN

MECHANICAL DRAWING

# MACHINE DRAWINGS

AND

# PROJECTIONS

*BOSTON, MASS., U.S.A.*

*1901*

ABCDEFGHIJKLMN

OPQRSTUVWXYZ

1234567890 & $2\frac{5}{8}$

Vertical Roman Capitals.

*ABCDEFGHIJKLMN*

*OPQRSTUVWXYZ*

*1234567890 & $2\frac{5}{8}$*

Inclined Roman Capitals.

ABCDEFGHIJKLMN

OPQRSTUVWXYZ

1234567890 & $2\frac{5}{8}$

Vertical Gothic Capitals.

*ABCDEFGHIJKLMN*

*OPQRSTUVWXYZ*

*1234567890 & $2\frac{5}{8}$*

Inclined Gothic Capitals.

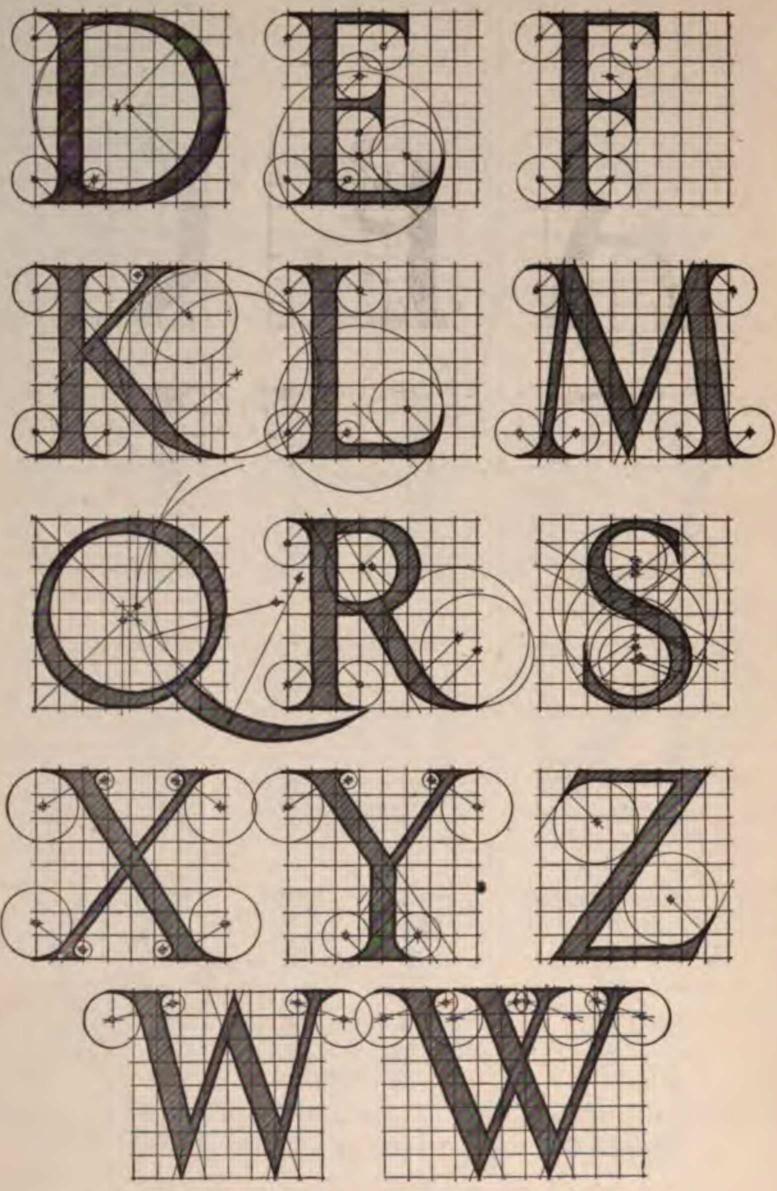
ABCDEFGHIJKLMN
OPQRSTUVWXYZ

Architectural Capitals.

ABCDEFGHIKLMN
OPQRSTVWXYZ

Architectural Capitals.

Architectural Alphabet of Classic Renaissance Letters according to Albrecht Durer, adapted and reconstructed by F. C. Brown.



Alphabet of Classic Renaissance Letters—Continued.

# MECHANICAL DRAWING.

## PART III.

## PROJECTIONS.

### ORTHOGRAPHIC PROJECTION.

Orthographic Projection is the art of representing objects of three dimensions by views on two planes at right angles to each other, in such a way that the forms and positions may be completely determined. The two planes are called planes of projection or co-ordinate planes, one being vertical and the other horizontal, as shown in Fig. 1. These planes are sometimes designated V and H respectively. The intersection of V and H is known as the ground line G L.

The view or projection of the figure on the plane gives the same appearance to the eye placed in a certain position that the object itself does. This position of the eye is at an infinite distance from the plane so that the rays from it to points of a limited object are all perpendicular to the plane. Evidently then the view of a point of the object is on the plane and in the ray through the point and the eye or where this perpendicular to the plane pierces it.

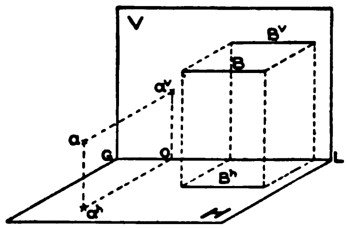


Fig. 1.

Let *a*, Fig. 1, be a point in space, draw a perpendicular from *a* to *V*. Where this line strikes the vertical plane, the projection of *a* is found, namely at $a^v$. Then drop a perpendicular from *a* to the horizontal plane striking it at $a^h$, which is the horizontal projection of the point. Drop a perpendicular from $a^v$ to H; this will intersect G L at *o* and be parallel and equal to the line $a\ a^h$. In the same way draw a perpendicular from $a^h$ to V, this also will intersect G L at *o* and will be parallel and equal to $a\ a^v$. In other words, the perpendicular to G L from the projection of a point on either plane equals the distance of the point from the other plane. B in Fig. 1, shows a line in space. $B^v$ is its V projection, and $B^h$

its H projection, these being determined by finding views of points at its ends and connecting the points.

Instead of horizontal projection and vertical projection, the terms **plan** and **elevation** are commonly used.

Suppose a cube, one inch on a side, to be placed as in Fig. 2, with the top face horizontal and the front face parallel to the vertical plane. Then the plan will be a one-inch square, and the elevation also a one-inch square. In general the plan is a representation of the top of the object, and the elevation a view of the front. The plan then is a top view, and the elevation a front view.

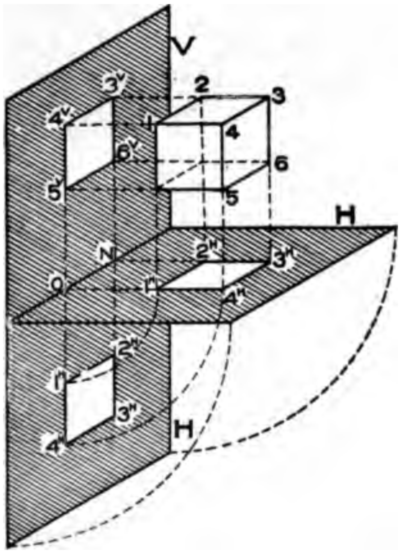



Fig. 2.

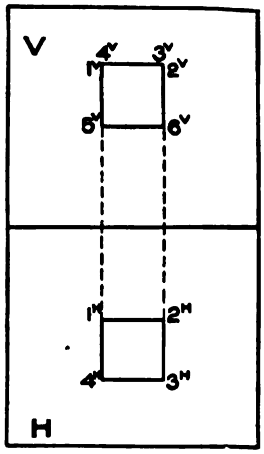



Fig. 3.

Thus far the two planes have been represented at right angles to each other, as they are in space. In order that they may be shown more simply and on the one plane of the paper, H is revolved about G L as an axis until it lies in the same plane as V as shown in Fig. 2. The lines $1^h$ O and $2^h$ N, being perpendicular to G L, are in the same straight line as $5^v$ O and $6^v$ N, which also are perpendicular to G L. That is—*two views of a point are always in a line perpendicular to G L.* From this it is evident that the plan must be vertically below the elevation, point for point. Now looking directly at the two planes in the revolved position, we get a true orthographic projection of the cube as shown in Fig. 3.

All points on an object at the same height must appear in elevation at the same distance above the ground line. If numbers 1, 2, 3, and 4 on the plan, Fig. 3, indicate the top corners of the cube, then these four points, being at the same height, must be shown in elevation at the same height and at the top, $\frac{4^v}{1^v}$ and $\frac{3^v}{2^v}$. The top of the cube, 1, 2, 3, 4, is shown in elevation as the straight line $\frac{4^v}{1^v}\ \frac{3^v}{2^v}$. This illustrates the fact that *if a surface is perpendicular to either plane or projection, its projection on that plane is simply a line; a straight line if the surface is plane, a curved line if the surface is curved.* From the same figure it is seen that the top edge of the cube, 1 4, has for its projection on the vertical plane the point $\frac{4^v}{1^v}$, the principle of which is stated in this way: *If a*

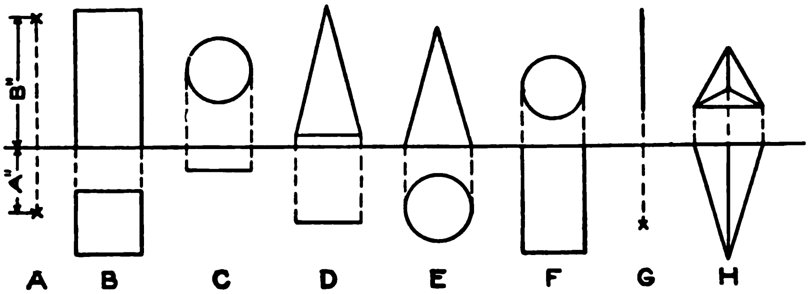


Fig. 4.

*straight line is perpendicular to either V or H, its projection on that plane is a point, and on the other plane is a line equal in length to the line itself, and perpendicular to the ground line.*

Fig. 4 is given as an exercise to help to show clearly the idea of plan and elevation.

A = a point B' above H, and A' in front of V.
B = square prism resting on H, two of its faces parallel to V,
C = circular disc in space parallel to V.
D = triangular card in space parallel to V.
E = cone resting on its base on H.
F = cylinder perpendicular to V, and with one end resting against V.
G = line perpendicular to H.
H = triangular pyramid above H, with its base resting against V.

Suppose in Fig. 5, that it is desired to construct the projections of a prism $1\frac{1}{2}$ in. square, and 2 in. long, standing on one end on the horizontal plane, two of its faces being parallel to the vertical plane. In the first place, as the top end of the prism is a square, the top view or plan will be a square of the same size, that is, $1\frac{1}{2}$ in. Then since the prism is placed parallel to and in front of the vertical plane the plan, $1\frac{1}{2}$ in. square, will have two edges parallel to the ground line. As the front face of the prism

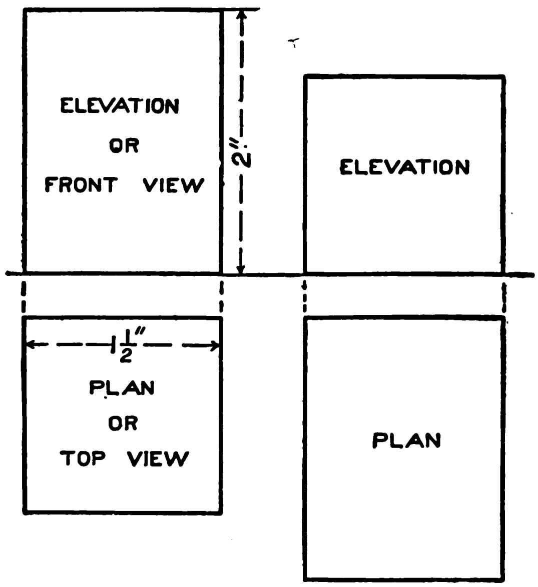



Fig. 5.

is parallel to the vertical plane its projection on V will be a rectangle, equal in length and width to the length and width respectively of the prism, and as the prism stands with its base on H, the elevation, showing height above H, must have its base on the ground line. Observe carefully that points in elevation are vertically over corresponding points in plan.

The second drawing in Fig. 5 represents a prism of the same size lying on one side on the horizontal plane, and with the ends parallel to V.

The principles which have been used thus far may be stated as follows, —

1. If a line or point is on either plane, its other projection must be in the ground line.

2. Height above H is shown in elevation as height above the ground line, and distance in front of the vertical plane is shown in plan as distance from the ground line.

3. If a line is parallel to either plane, its actual length is shown on that plane, and its other projection is parallel to the ground line. A line obliquo to either plane has its projection on that plane shorter than the line itself, and its other projection oblique to the ground line. No projection can be longer than the line itself.

4. A plane surface if parallel to either plane, is shown on

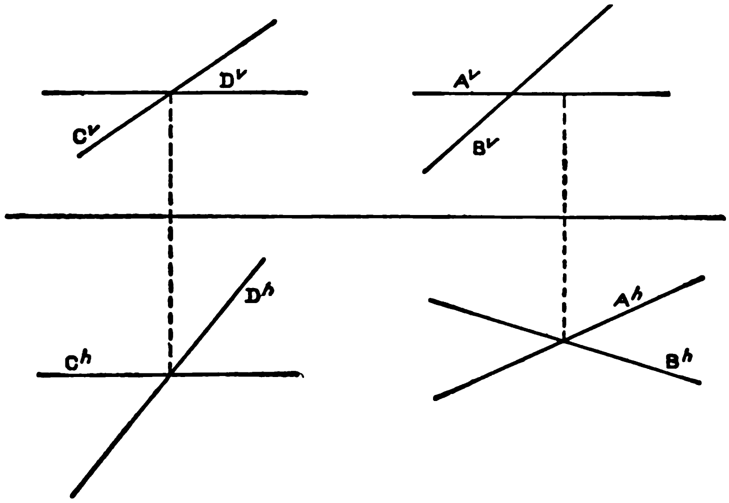



Fig. 6. Fig. 7.

that plane in its true size and shape; if oblique it is shown smaller than the true size, and if perpendicular it is shown as a straight line. Lines parallel in space must have their V projections parallel to each other and also their H projections.

If two lines intersect, their projections must cross, since the point of intersection of the lines is a point on both lines, and therefore the projections of this point must be on the projections of both lines, or at their intersection. In order that intersecting lines may be represented, the vertical projections must intersect in a point vertically above the intersection of the horizontal projections. Thus Fig. 6 represents two lines which do intersect as $C^v$ crosses $D^v$ at a point vertically above the intersection of $C^h$ and $D^h$. In Fig. 7, however, the lines do not intersect since the intersections of their projections do not lie in the same vertical line.

In Fig. 8 is given the plan and elevation of a square pyramid standing on the horizontal plane. The height of the pyramid is the distance A B. The slanting edges of the pyramid, A C, A D, etc., must be all of the same length, since A is directly above the center of the base. What this length is, however, does not appear in either projection, as these edges are not parallel to either V or H.

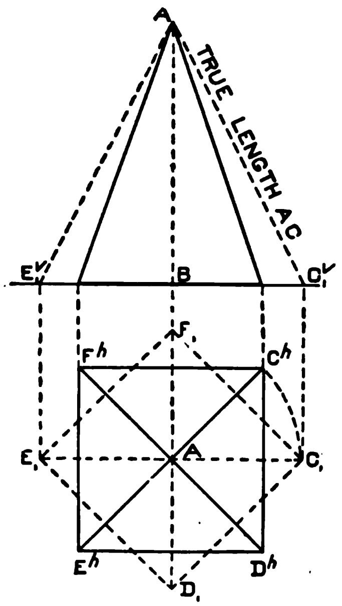
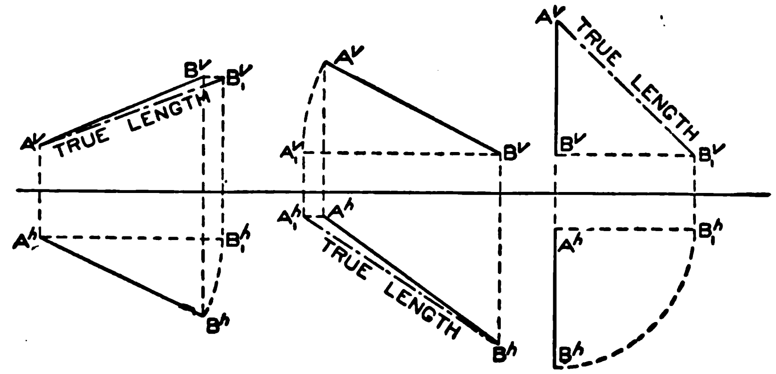


Fig. 8.

Suppose that the pyramid be turned around into the dotted position $C_1$ $D_1$ $E_1$ $F_1$ where the horizontal projections of two of the slanting edges, A $C_1$ and A $E_1$ are parallel to the ground line. These two edges, having their horizontal projections parallel to the ground line, are now parallel to V, and therefore their new vertical projections will show their true lengths. The base of the pyramid is still on H, and therefore is projected on V in the ground line. The apex is in the same place as before, hence the vertical projection of the pyramid in its new position is shown by the dotted lines. The vertical projection A $C_1{}^v$ is the true length of edge A C. Now if we wish to find simply the true length of A C, it is unnecessary to turn the whole pyramid around, as the one line A C will be sufficient.

The principle of finding the true length of lines is this, and can be applied to any case: Swing one projection of the line parallel to the ground line, using one end as center. On the other projection the moving end remains at the same distance from the ground line, and of course vertically above or below the same end in its parallel position. This new projection of the line shows its true length. See the three Figures at the top of page 9.

**Third plane of projection or profile plane.** A plane perpendicular to both co-ordinate planes, and hence to the ground line, is




called a *profile plane*. This plane is vertical in position, and may be used as a plane of projection. A projection on the profile plane is called a profile view, or *end view*, or sometimes edge view, and is often required in machine or other drawing when the plan and elevation do not sufficiently give the shape and dimensions.

A projection on this plane is found in the same way as on the

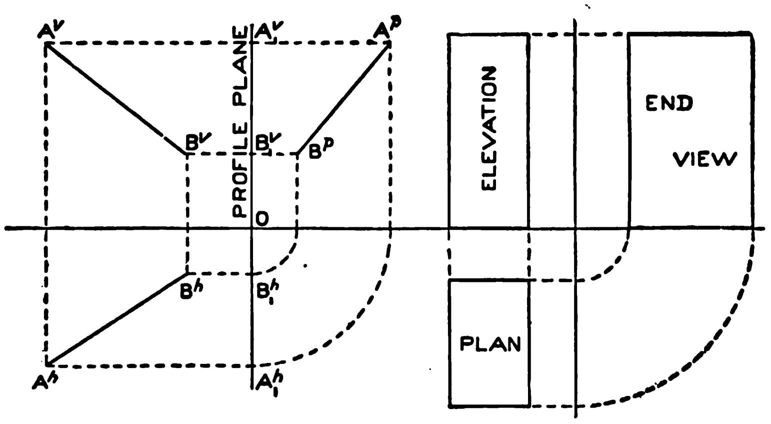



Fig. 9.

V plane, that is, by perpendiculars drawn from points on the object.

Since, however, the profile plane is perpendicular to the ground line, it will be seen from the front and top simply as a straight line; in order that the size and shape of the profile view may be shown, the profile plane is revolved into V using its intersection with the vertical plane as the axis.

Given in Fig. 9, the line A B by its two projections $A^v$ $B^v$ and $A^h$ $B^h$, and given also the profile plane. Now by projecting the line on the profile by perpendiculars, the points $A_1^v$ $B_1^v$ and $B_1^h$ $A_1^h$ are found. Revolving the profile plane like a door on its hinges, all points in the plane will move in horizontal circles, so the horizontal projections $A_1^h$ and $B_1^h$ will move in arcs of circles with O as center to the ground line, and the vertical projections $B_1^v$ and $A_1^v$ will move in lines parallel to the ground line to positions directly above the revolved points in the ground line, giving the profile view of the line $A^p$ $B^p$. Heights, it will be seen, are the same in profile view as in elevation. By referring to the rectangular prism in the same figure, we see that the elevation gives vertical dimensions and those parallel to V, while the end view shows vertical dimensions and those perpendicular to V. The profile view of any object may be found as shown for the line A B by taking one point at a time.

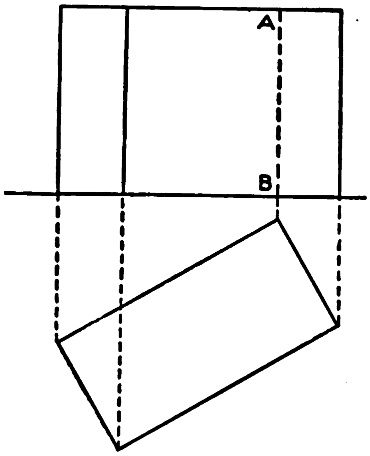



Fig. 10.

In Fig. 10 there is represented a rectangular prism or block, whose length is twice the width. The elevation shows its height. As the prism is placed at an angle, three of the vertical edges will be visible, the fourth one being invisible.

In mechanical drawing lines or edges which are invisible are drawn *dotted*. The edges which in projection form a part of the outline or contour of the figure must always be visible, hence always *full lines*. The plan shows what lines are visible in elevation, and the elevation determines what are visible in plan. In Fig. 10, the plan shows that the dotted edge A B is the back edge, and in Fig. 11, the dotted edge C D is found, by looking at the elevation, to be the lower edge of the triangular prism. In general, if in elevation an edge projected *within* the figure is a back edge, it must be dotted, and in plan if an edge projected within the outline is a lower edge it is dotted.

Fig. 12 is a circular cylinder with the length vertical and

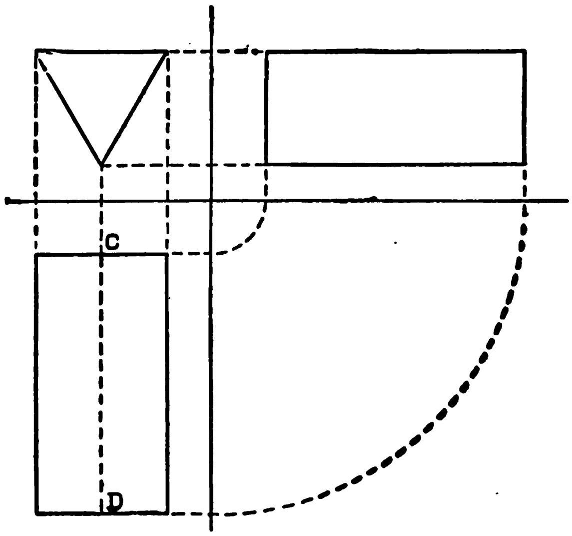



Fig. 11.

with a hole part way through as shown in elevation. Fig. 13 is plan, elevation and end view of a triangular prism with a square hole from end to end. The plan and elevation alone would be insufficient to determine positively the shape of the hole, but the end view shows at a glance that it is square.

In Fig. 14 is shown plan and elevation of the frustum of a square pyramid, placed with its base on the horizontal plane. If the frustum is turned through 30°, as shown in the plan of Fig. 15, the top view or plan must still be the same shape and size, and as the frustum has not been raised or lowered, the heights of all points must appear the same in elevation as before in Fig. 14. The elevation is easily found by projecting points up from the plan, and projecting the height of the top horizontally across from the first elevation, because the height does not change.

The same principle is further illustrated in Figs. 16 and 17. The elevation of Fig. 16 shows a square prism resting on one edge, and raised up at an angle of 30° on the right-hand side. The plan gives the width or thickness, $\frac{5}{8}$ in. Notice that the length of the plan is greater than 2 in. and that varying the angle at

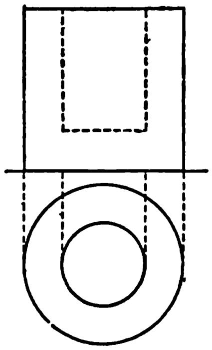


Fig. 12.

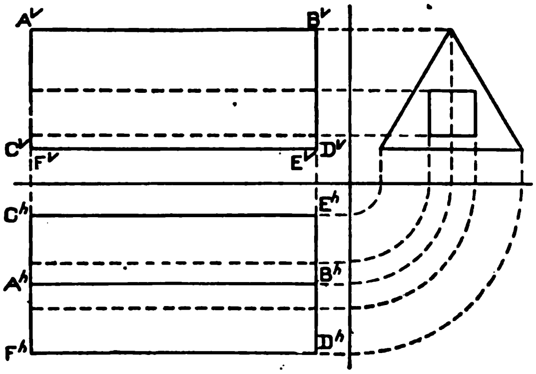



Fig. 13.

which the prism is slanted would change the length of the plan. Now if the prism be turned around through any angle with the vertical plane, the lower edge still being on H, and the inclination

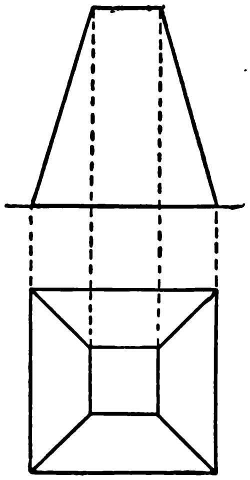


Fig. 14.

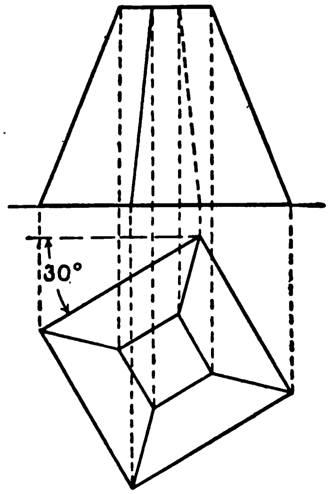



Fig. 15.

of 80° with H remaining the same, the plan must remain the same size and shape.

If the angle through which the prism be turned is 45°, we have the second plan, exactly the same shape and size as the first. The elevation is found by projecting the corners of the prism ver-

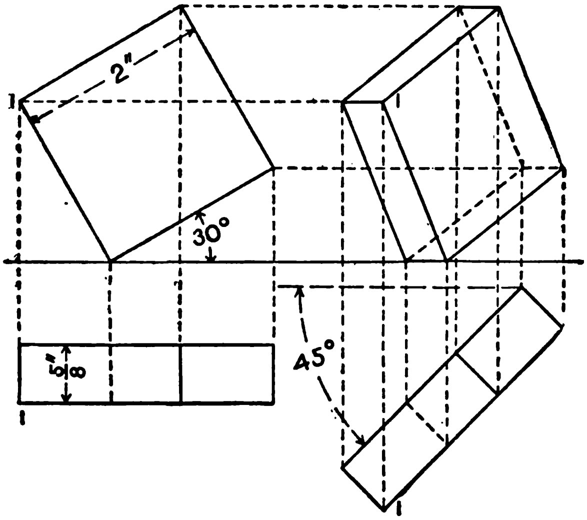



Fig. 16.

tically up to the heights of the same points in the first elevation. All the other points are found in the same way as point No. 1.

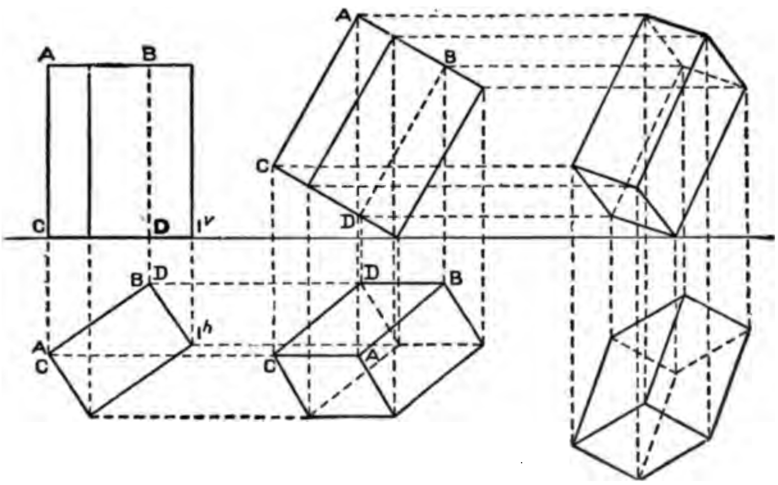



Fig. 17.

Three positions of a rectangular prism are shown in Fig. 17. In the first view, the prism stands on its base, its axis therefore is parallel to the vertical plane. In the second position, the axis is still parallel to V and one corner of the base is on the horizontal plane. The prism has been turned as if on the line $1^h$ $1^v$ as an axis, so that the inclination of all the faces of the prism to the vertical plane remains the same as before. That is, if in the first figure the side A B C D makes an angle of 30° with the vertical, the same side in the second position still makes 30° with the ver-

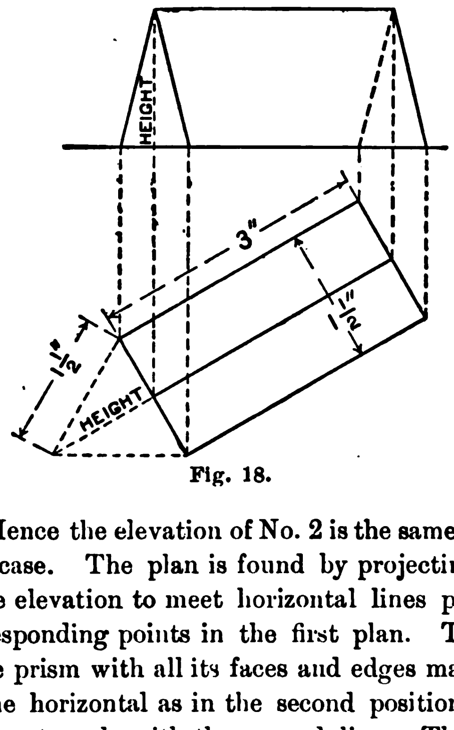



Fig. 18.

tical plane. Hence the elevation of No. 2 is the same shape and size as in the first case. The plan is found by projecting the corners down from the elevation to meet horizontal lines projected across from the corresponding points in the first plan. The third position shows the prism with all its faces and edges making the same angles with the horizontal as in the second position, but with the plan at a different angle with the ground line. The plan then is the same shape and size as in No. 2, and the elevation is found by projecting up to the same heights as shown in the preceeding elevation. This principle may be applied to any solid, whether bounded by plane surfaces or curved.

This principle as far as it relates to heights, is the same that was used for profile views. An end view is sometimes necessary before the plan or elevation of an object can be drawn. Suppose that in Fig. 18 we wish to draw the plan and elevation of a triangular prism 3" long, the end of which is an equilateral triangle

$1\frac{1}{2}''$ on each side. The prism is lying on one of its three faces on H, and inclined toward the vertical plane at an angle of 30°. We are able to draw the plan at once, because the width will be $1\frac{1}{2}$ inches, and the top edge will be projected half way between the other two. The length of the prism will also be shown. Before we can draw the elevation, we must find the height of the top edge. This height, however, must be equal to the altitude of the triangle forming the end of the prism. All that is necessary, then, is to construct an equilateral triangle $1\frac{1}{2}''$ on each side, and measure its altitude.

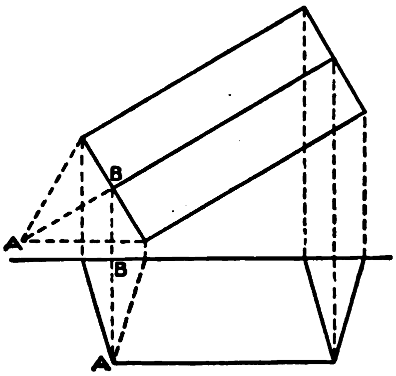



Fig. 19.

A very convenient way to do this is shown in the figure by laying one end of the prism down on H. A similar construction is shown in Fig. 19, but with one face of the prism on V instead of on H.

In all the work thus far the plan has been drawn below and the elevation above. This order is sometimes inverted and the plan put above the elevation.

## PLATES.

### PLATE V..

The plates of this paper should be laid out the same size as the plates in Part I. The center lines and border lines should also be drawn as shown.

First draw two ground lines across the sheet, 3 inches below the upper border line and 3 inches above the lower border line. The first problem on each ground line is to be placed 1 inch from the left border line and spaces of about 1 inch should be left between the figures.

Isolated points are indicated by a small cross ×, and projections of lines are to be drawn full unless invisible. All construction lines should be fine dotted lines. Given and required lines should be drawn full.

**Problems on upper ground line;**

PROBLEM 1. Locate both projections of a point on the horizontal plane 1 inch from the vertical plane.

PROBLEM 2. Draw the projections of a line 2 inches long which is parallel to the vertical plane and makes an angle of 45 degrees with the horizontal and slants upward to the right.

The line should be 1 inch from the vertical plane and the lower end ½ inch above the horizontal.

PROBLEM 3. Draw the projections of a line 1½ inches long, which is parallel to both planes 1 inch above the horizontal and ¾ inch from the vertical.

PROBLEM 4. Draw the plan and elevation of a line 2 inches long which is parallel to H and makes an angle of 30 degrees with V. Let the right-hand end of the line be the end nearer V, ½ inch from V. The line to be 1 inch above H.

PROBLEM 5. Draw the plan and elevation of a line 1½ inches long which is perpendicular to the horizontal plane and 1 inch from the vertical. The lower end of line is ½ inch above H.

PROBLEM 6. Draw the projections of a line 1 inch long which is perpendicular to the vertical plane and 1½ inch above the horizontal. The end of the line nearer V, or the back end, is ½ inch from V.

PROBLEM 7. Draw two projections which shall represent a line oblique to both planes.

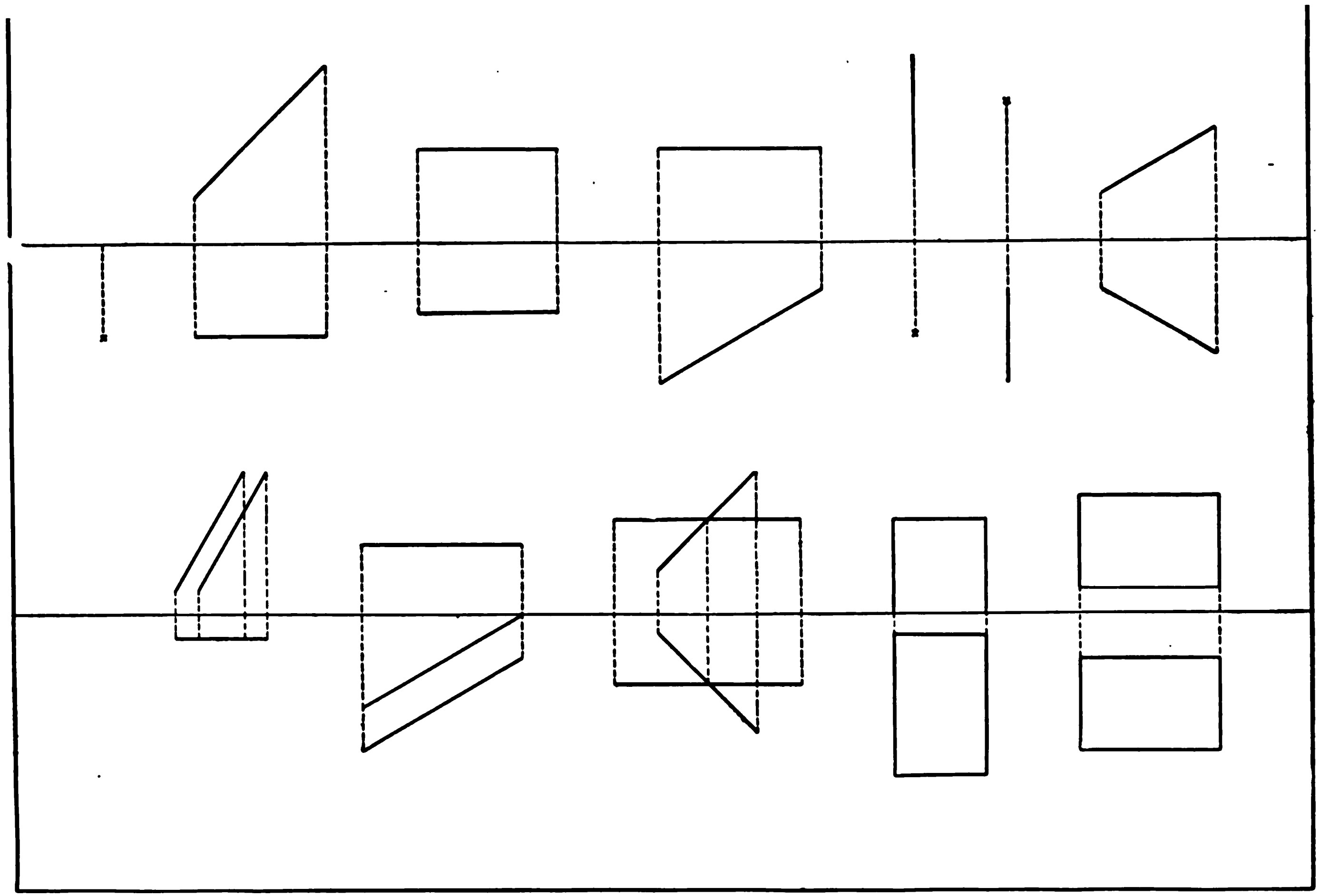
NOTE: Leave 1 inch between this figure and the right-hand border line.

**Problems on lower ground line.**

PROBLEM 8. Draw the projections of two parallel lines each 1½ inches long. The lines are to be parallel to the vertical plane and make angles of 60 degrees with the horizontal. The lower end of each line is ¼ inch above H. The right-hand end of the right-hand line is to be 2¾ inches from the left-hand margin.

PROBLEM 9. Draw the projections of two parallel lines each 2 inches long. Both lines to be parallel to the horizontal and make an angle of 30 degrees with the vertical. The lower line to be ¾ inch above H and one end of one line to be against V.

PROBLEM 10. Draw the projections of two intersecting lines. One 2 inches long to be parallel to both planes 1 inch



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above H and $\frac{3}{4}$ inch from the vertical, and the other to be oblique to both planes and of any desired length.

PROBLEM 11. Draw plan and elevation of a prism 1 inch square and $1\frac{1}{2}$ inches long. The prism to have one side on the horizontal plane and the long edges perpendicular to V. The back end of the prism is $\frac{1}{4}$ inch from the vertical plane.

PROBLEM 12. Draw plan and elevation of a prism the same size as given above, but with the long edges parallel to both planes, the lower face of prism parallel to H and $\frac{1}{4}$ inch above it. The back face to be $\frac{1}{2}$ inch from V.

## PLATE VI.

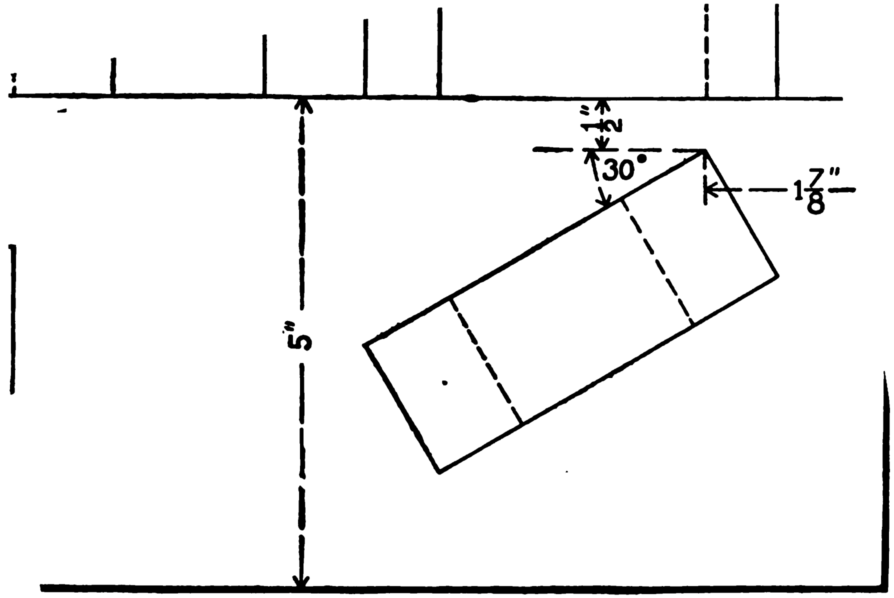
The ground line is to be in the middle of the sheet, and the location and dimensions of the figures are to be as given. The first figure shows a rectangular block with a rectangular hole cut through from front to back. The other two figures represent the same block in different positions. The second figure is the end or profile projection of the block. The same face is on H in all three positions. Be careful not to omit the shade lines, and try to see why each one is put on.

## PLATE VII.

Three ground lines are to be used on this plate, two at the left, $4\frac{1}{2}''$ long and $3''$ from top and bottom margin lines, and one at the right, half way between the top and bottom margins, $9\frac{1}{2}''$ long.

The figures 1, 2, 3 and 4 are examples for finding the true lengths of the lines. Begin No. 1 $\frac{3}{4}''$ from the border, the vertical projection $1\frac{3}{4}''$ long, one end on the ground line, and inclined at 30°. The horizontal projection has one end $\frac{1}{2}''$ from V and the other $1\frac{1}{2}''$ from V. Find the true length of the line by completing the construction commenced by swinging the arc, as shown in the figure.

Locate the left-hand end of No. 2 $3''$ from the border, $1''$ above H and $\frac{5}{8}''$ from V. Extend the vertical projection to the ground line at an angle of 45°, and make the horizontal projection at 30°. Complete the construction for true length as commenced in the figure.

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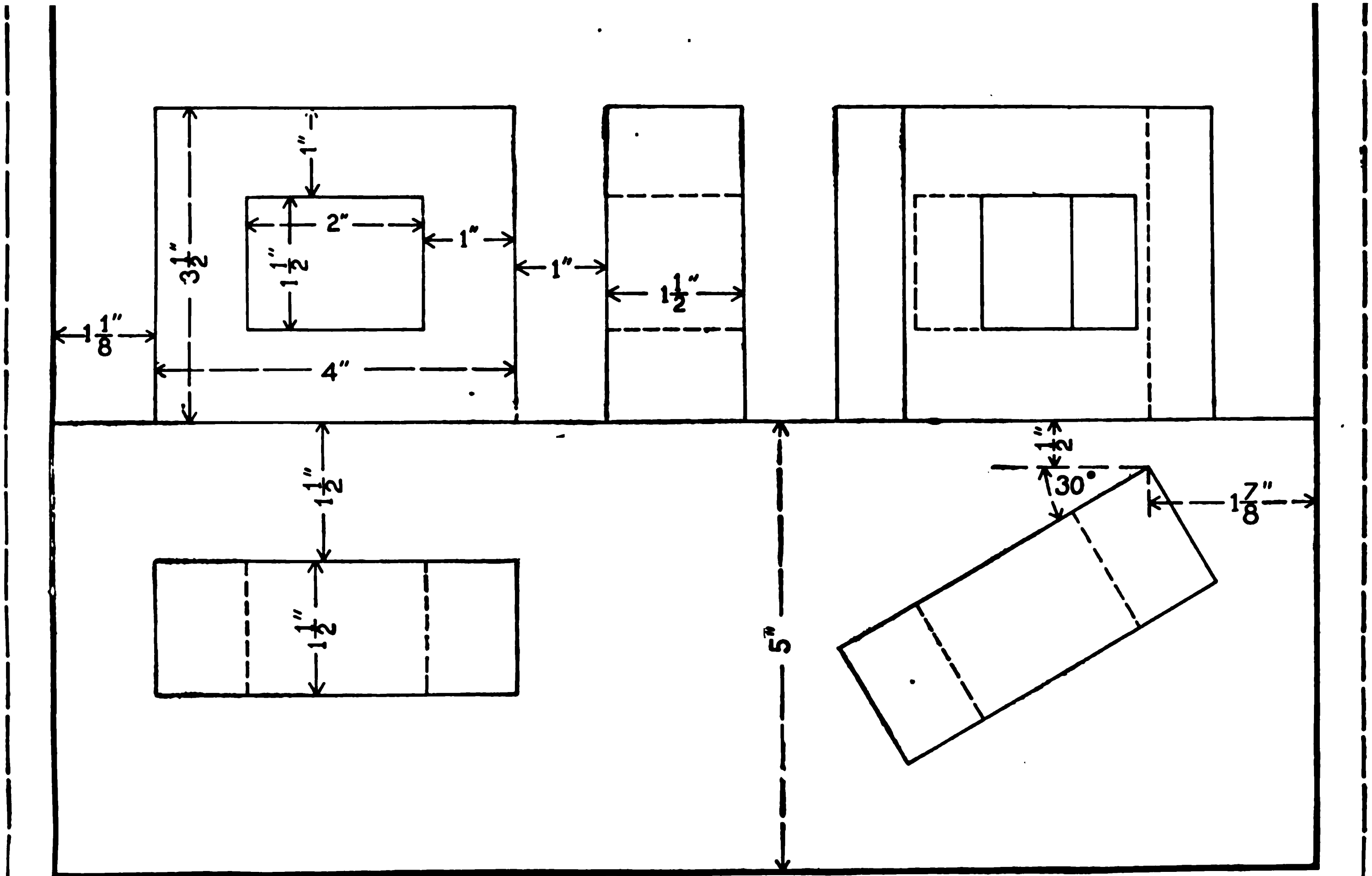
In figures 3 and 4 the true lengths are to be found by completing the revolutions indicated. The left-hand end of Fig. 3 is $\frac{3}{4}''$ from the margin, $1\frac{1}{2}''$ from V and $1\frac{3}{8}''$ above H. The horizontal projection makes an angle of 60° and extends to the ground line, and the vertical projection is inclined at 45°.

The fourth figure is 3″ from the border and represents a line in a profile plane connecting points *a* and *b*. *a* is $1\frac{1}{4}''$ above H and $\frac{3}{4}''$ from V, and *b* is $\frac{1}{4}''$ above H and $1\frac{1}{2}''$ from V.

The figures for the middle ground line represent a pentagonal pyramid in three positions. The first position is the pyramid with the axis vertical and base $\frac{5}{8}''$ above the horizontal. The height of pyramid is $2\frac{1}{2}''$ and the diameter of the circle circumscribed about the base is $2\frac{1}{2}''$. The center of the circle is 6″ from the left margin and $1\frac{3}{4}''$ from V. Spaces between figures to be $\frac{3}{4}''$.

In the second figure the pyramid has been revolved about the right-hand corner of the base as an axis through an angle of 15°. The axis of the pyramid, shown dotted, is therefore at 75°. The method of obtaining 75° and 15° with the triangles was shown in Part I. From the way in which the pyramid has been revolved, all angles with V must remain the same as in the first position, hence the vertical projection will be the same shape and size as before. The points on the plan are found on T-square lines through the corners of the first plan and directly beneath the points in elevation. In the third position the pyramid has been swung around about a vertical line through the apex as axis through 30°. The angle with the horizontal plane remains the same, consequently the plan is the same size and shape as in the second position, but at a different angle with the ground line. Heights of all points of the pyramid have not changed this time, and hence are projected across from the second elevation. Shade lines are to be put on between the light and dark surfaces as determined by the 45° triangle.

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# MECHANICAL DRAWING.

## PART III.

### WORKING DRAWINGS.

In Mechanical Drawing Parts I and II, instruments and materials are described and some hints given regarding the use of compasses, line pen, triangles, T-square, etc. In addition, the general principles upon which all Mechanical Drawing depends, are explained. After completing this work the student should be able to draw neatly and accurately and apply the fundamental principles.

Let us now take up the subject of working drawings and see how the principles of orthographic projection are made of practical use. We shall see, as we go on, that to a great extent the theoretical principles already learned in the study of projections are used in practical working shop drawings. Nevertheless, there are certain instances in which actual practice differs slightly from the theory.

We shall also find that all draftsmen do not follow the same customs in the matter of minor details, but that in many cases there are several ways of representing objects, all of which may be equally correct, one draftsman using one method either because he prefers it or because it best serves the purpose for which his particular work is being done, while another draftsman uses a different method. The more important principles and customs, however, are pretty well established.

A study of the subject of working drawings should, first, teach us the methods of the best drafting rooms; second, should train our judgment to decide how best to represent the particular object which we have to draw; third, should train our hand and eye to make a clear, neat and well-executed drawing, without unnecessary expenditure of time.

**Definition of Working Drawing.** A working drawing of any object is a drawing which completely describes the object in every particular, showing its form, size, material, finish, and all other details, so that a workman may take the drawing and without any further instructions make the object exactly as the draftsman intended it to be made. The drawing is, therefore, a sort of language, by which the man who designs the object describes it to the man who is to make it. Fig. 1 shows the working drawing of a bell crank lever. The drawing itself shows the shape and the dimensions show the size.

Aside from drawings of buildings, etc., that is Architectural drawings, the greater part of the working drawings which are made are for machines, and we will consider chiefly the latter, or, as they are called, machine drawings. These drawings are almost always orthographic projections, as this is by far the easiest and best way to represent a machine or a part of a machine. Some-

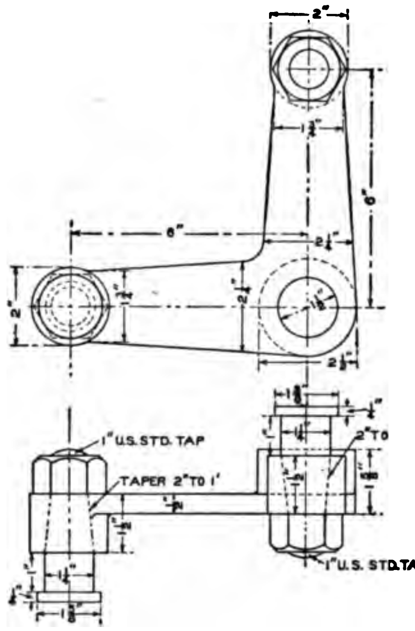



Fig. 1.

times, when it is desired to give a sort of bird's-eye view of a machine, an isometric or an oblique projection is made, but this method involves so much labor that it is seldom used.

**Lines.** In order to make a drawing perfectly clear, and to avoid confusing one line with another, different kinds of lines are used for different purposes. Fig. 2 shows the six most common kinds used. The ordinary *full lines* are used to represent visible lines of the object which is being drawn.

The *invisible lines* are used to represent lines of the object which would be hidden from sight if a person looked in the direction in which he imagines himself to be looking while he is drawing it.

The use of the *shade lines* will be explained later.

*Center lines* are used to connect different views of an object, the line being drawn through the center of the piece and extending through both views. Locations of holes are usually shown by having two center lines drawn at right angles to each other through their centers, and the position of these center lines located. Wherever a dimension is to be given to the center of a piece a center line is drawn through the piece and the dimension given to this line.

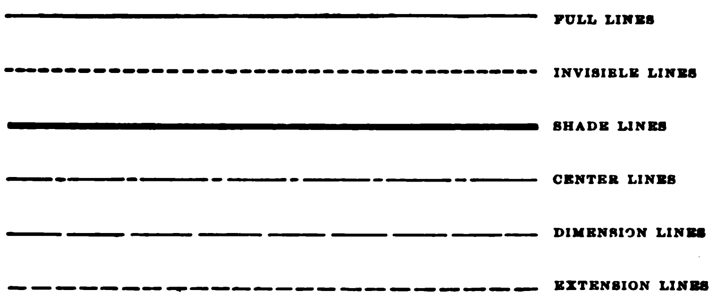



Fig. 2.

*Extension lines* are sometimes used to connect two views of a piece, but, wherever it is possible to use a center line, instead, the latter is preferable. The principal use of extension lines is, as the name implies, to extend the lines of the object so as to give dimensions between them.

*Dimension lines* are used in giving dimensions from one line or point to another.

The ordinary lines and the invisible lines should be made of the same width; the shade lines should be made considerably heavier, and the center lines, extension lines and dimension lines should be lighter.

**Location of Views.** In our preceding study of projections we imagined our object to be held in the angle formed by two planes which intersect at right angles, the planes and the object being supposed to be in the position represented in Fig. 3, the horizontal plane H being below the object and the vertical plane V being beside the object. We then projected down to the horizontal plane and represented there the object as it would appear if seen squarely in the direction indicated by arrow A. We next projected into the vertical plane, and represented the object as it

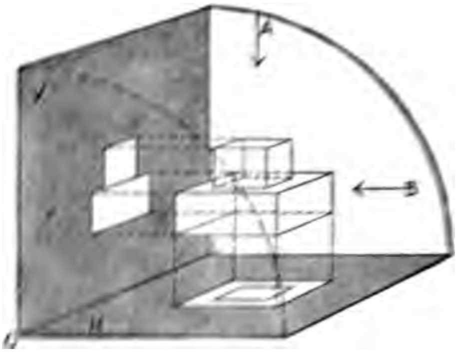


Fig. 3.

would appear if the line of vision took the direction of the arrow B. Our planes, with the horizontal and vertical projections of the object on them, when laid out flat, as a sheet of paper is when we actually draw on it, would appear as in Fig. 4, the horizontal projection, or top view, being *underneath* the vertical projection, or side view. This is the practice followed by some draftsmen in making working drawings. Many of the best draftsmen, however, think that it is not as clear and convenient to have the top view of the object underneath the side view, but that it is better to have the view of the top above the other view. Consequently, it is becoming more and more a general custom to suppose the planes to be

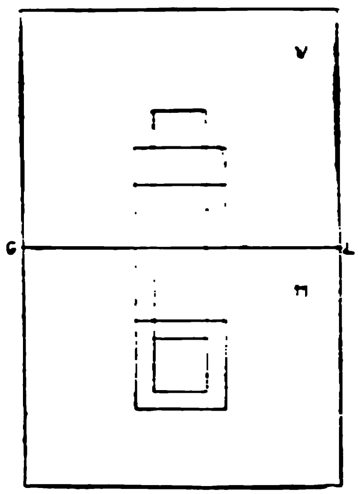



Fig. 4.

transparent and to be located with respect to the piece which is being drawn as shown in Fig. 5, the H plane being above the object and the V plane in front of the object. They then draw on the H plane the object as it appears when looking at it through the transparent plane in the direction indicated by arrow C, and on the V plane the object as it appears when looking in direction of arrow D. Now, when the two planes are laid out flat, the top view is above the side view, as in Fig. 6.

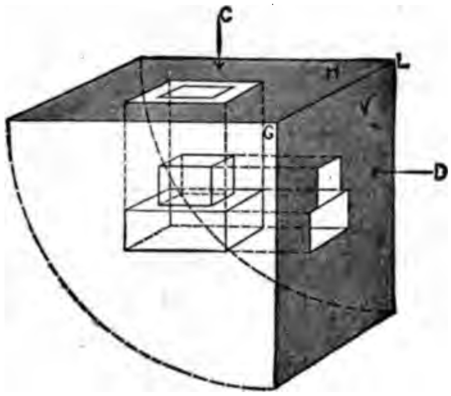



Fig. 5.

Another way of showing this is to suppose the object to be located in a transparent box, and that we look at it from the top and the various sides of the box, and draw on these sides the object as it appears from that side. Then, if the sides of the box are laid out flat, the side view will come in the middle, with the top view above, the view of the bottom underneath, the view of the right-hand side on the right, and the view of the left-hand side on the left.

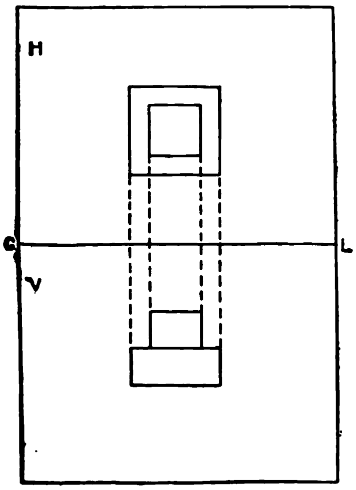



Fig. 6.

From now on, in our work on drawing, we shall follow this rule.

**Cross-sections.** Very often it occurs that a piece is hollow and the inside construction is more or less complicated, so that if in the drawing the outside view is shown, with the invisible interior drawn in dotted lines, the latter are so confused that the drawing is not easily understood. For this reason it is often convenient to imagine the piece to be cut open, and to draw it as if we were looking directly at the inside. Such a drawing of a piece is called a cross-section of the piece. The material which must be cut if the object were actually split open is then crosshatched, different kinds of crosshatching being used for different materials. Fig. 7 shows the kinds of cross-hatching in ordinary use.

Fig. 8 shows a plan and elevation of a simple piece with a hole through it, the hole being shown in the elevation by dotted lines. Fig. 9 shows a plan and a cross-section of the same piece, the cross-section being drawn as if we were looking in the same direction as in the elevation of Fig. 8, but in Fig. 9 the front half is supposed to be cut away and we are looking at the inside of the back half. It will be observed that even on a piece as

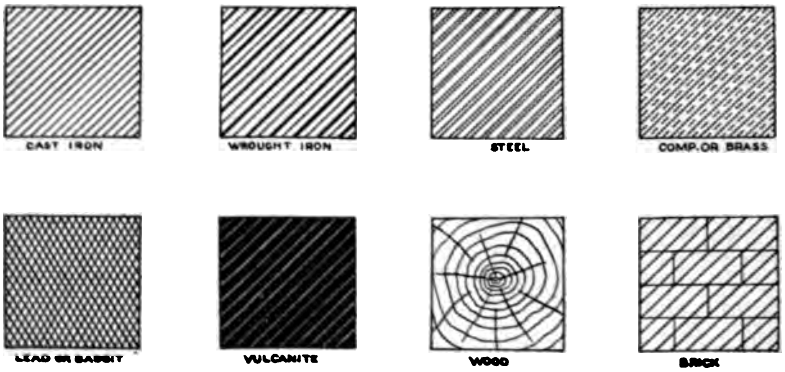



Fig. 7.

simple as the one here shown, the shape of the interior is much clearer from the cross-section than from the elevation, and on a more complicated piece the same will be true to a greater extent.

It should be borne in mind that ordinarily in making a cross-section we show not only those parts of the object which lie in the plane in which it is supposed to be cut, but also all which lie back of that plane.

Sometimes it is desirable to show the inside and the outside of a piece on the same view. Fig. 10 shows the same piece as in Fig. 8, but in Fig 10 the left-hand half of the lower view is an [illegible] the right-hand half is a cross-section, the section and [illegible] can be used only when the right-hand and left-hand halves of the piece are alike.

**Shade Lines.** In order to make drawings easier to read, and to make the parts of the object stand out more clearly, shade lines are often put on the drawing. The general principle which determines what lines shall be shade lines is the same as that which governs shade lines already studied under the subject of projections. If, however, this theoretical principle were to be followed out exactly on drawings of machines, and other complicated drawings, it would involve a great deal of time and labor.

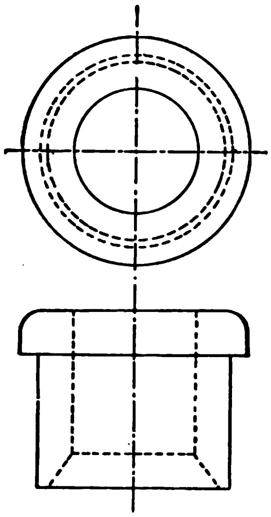


Fig. 8.

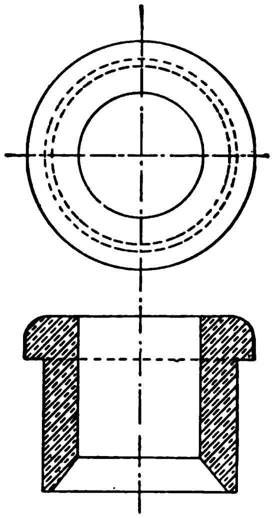


Fig. 9.

Consequently, most draftsmen place shade lines on all lines which represent lower and right-hand edges if these edges are sharp.

The contour lines of cylinders, cones and other rounded surfaces should not be shade lines, although some draftsmen shade them. If the cylinder is drawn in cross-section, however, the edge should be shaded, as the intersection of the plane and cylindrical surface is a sharp edge.

All views are shaded alike, and both are shaded as though they were elevations. The ray of light is supposed to come over the left shoulder of the draftsman, as he faces the paper, at such an angle that the projection of the ray of light on the drawing paper is in the direction of the arrow in Fig. 11.

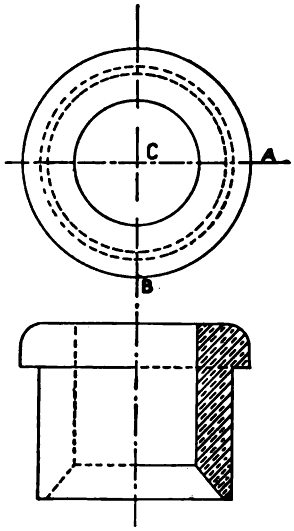



Fig. 10.

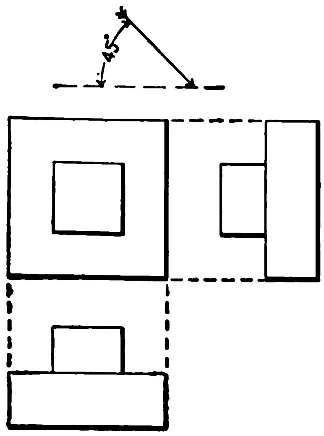



Fig. 11.

Figs. 11 to 18 show some of the most common shapes met with in drawings, and illustrate how the shade lines are placed on each. Fig. 11 is an elevation, plan, and side view of a rectangular

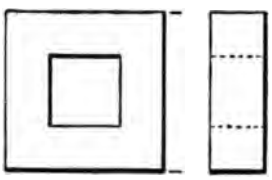


Fig. 12.

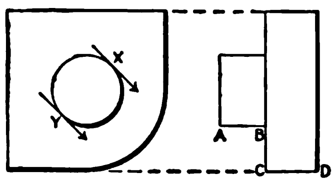



Fig. 13.

prism with a smaller one resting on top of it. Fig. 12 is a plan and side view of a rectangular prism with a rectangular hole through it. It is to be noticed that the shade lines come on the upper and left-hand sides of the hole, since these lines are the

**lower and right-hand edges of the material which surrounds the hole. Fig. 13 is a plan and side view of a rectangular prism with one corner rounded, and with a cylinder resting on it. Here the lines A B and C D are not shaded, since they are the contour lines of curved surfaces. In the plan view, the lower right-hand part of the circle, between X and Y, is shaded. To find these points X and Y, draw two lines tangent to the circle and making an angle of 45° with the T-square line as shown by the arrows; X and Y are the points where the arrows are tangent to the circle. Fig. 14 is a plan, elevation and cross-section of a cylinder.**

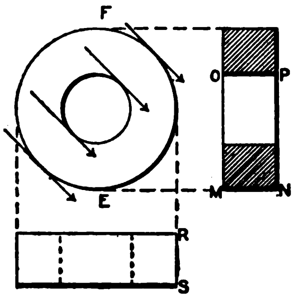



**Fig. 14.**

**Here, in the plan, the larger circle is shaded on the lower side, and the circle which represents the hole is shaded on the upper side. The points where the shade begins are determined as explained for Fig. 13. The lines M N and O P are shaded since,**

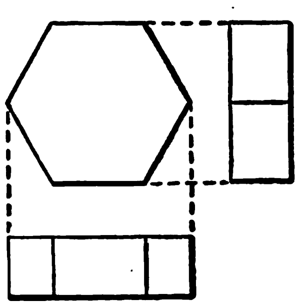


**Fig. 15.**

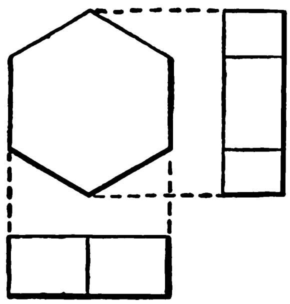


**Fig. 16.**

**as the cylinder is supposed to be cut open, these lines now represent sharp edges. Fig. 15 is a plan, elevation and side view of a hexagonal prism with its long diameter parallel to the bottom of the paper. Fig. 16 is the same except that here the short diameter of the prism is parallel to the bottom of the paper. Fig. 17 is a plan and end view of a rectangular block with a wide slot of the shape H I J K M L O N, cut through it lengthwise. The main point to which attention should be called here is that the line**

C D is shaded, although the slot might be so deep that the light might not strike in there because of the shadow of the projecting lip marked in the side view G H I. Fig. 18 is a cross-section and end view of a circular cylinder with a large hole extending part way through and a smaller hole extending the rest of the way. The small circle in the end view is shaded, although it is so far in that no light could strike it.

The student should study these figures carefully, and before

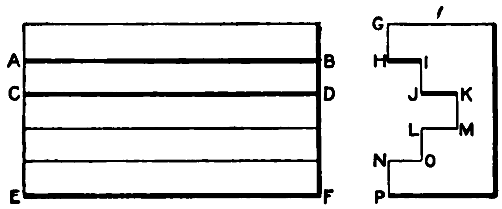



Fig. 17.

leaving them should understand what each figure means and how the shade lines are determined, so that when he meets similar forms in machine drawings he may know where the shade lines should be placed.

**Dimensions.** In giving the distance from one line to another, a dimension line is drawn between the two lines and arrowheads

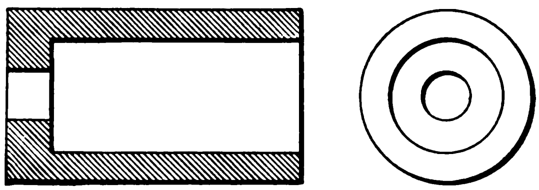


Fig. 18.

are placed at each end of the dimension line; the points of the arrowheads being *exactly on* the lines to which the measurement is being given. At a convenient place between the arrowheads a space is left in the dimension line for the figure.

Fig. 19 is a plan and elevation of a rectangular piece with a cylinder on the center of its upper surface, and with four holes through it; the holes being symmetrically located with respect to the center line of the piece; that is, the holes A and B are just as far above the center line E F as C and D are below it, and the holes B and D are just as far to the right of the center line G H as A and C are to the left of it. The fact that the cylinder is on the center of the rectangular piece is shown by the lines E F and G H being drawn through the center of the circle in the plan view, these lines being the center lines both of the cylinder and of the rectangular piece. If the cylinder were not on the center, two other center lines would be drawn through the circle and the dimensions given from each of these lines to the center lines of the rectangular piece, or to the edges of the piece. The fact that the holes are symmetrically located is shown by the dimensions being given between the center lines of the holes and no dimensions being given from these center lines to the center lines of the piece.

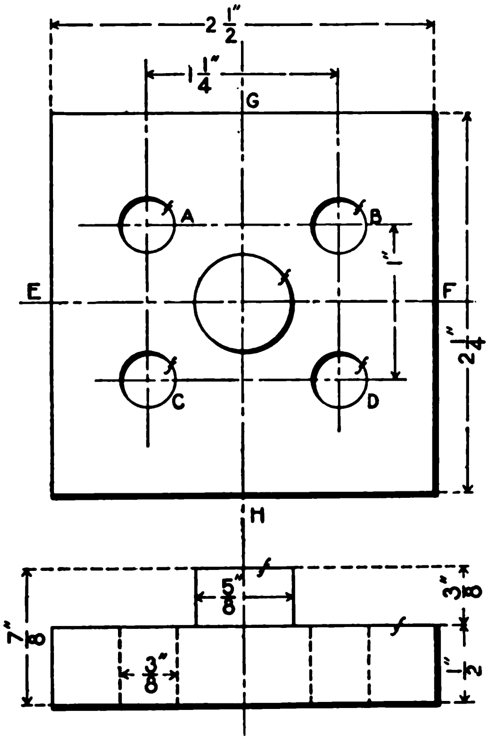



Fig. 19.

Fig. 20 shows how the piece might be dimensioned if the cylinder were not on the center of the rectangular piece and the holes were not symmetrically located with respect to the center of the rectangular piece.

If the centers of a set of holes are so located that a circle can be drawn through them, we always locate the holes by drawing a center line circle through their centers and giving the diameter of this circle, and if no other dimension than this is given for the location of the holes, it is understood that they are equally spaced around this circle. Fig. 21 illustrates this. If the holes are not equally spaced around the circle, they may be located as shown in Fig. 22.

Diameters of circles, and of arcs of circles which are greater than semicircles, should be given rather than radii, but if the arc of the circle is less than a semicircle, its radius should be given. Fig. 23 shows how this should be done when the radius is large enough to permit; but if the radius is small, or the dimensions would interfere with other parts of the drawing, it may be done as in Fig. 24.

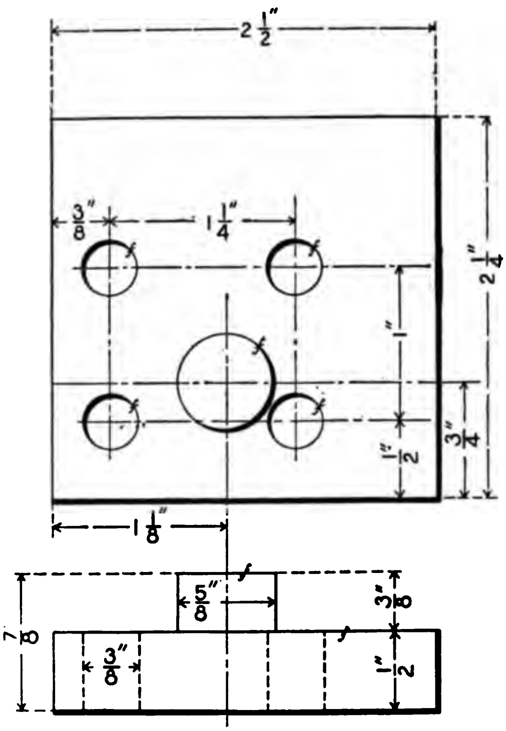



Fig. 20.

In Fig. 23 a small circle is drawn (free hand) around the center about which the arc is drawn, and a dimension line carried from the edge of this circle to the arc; an arrowhead being placed on the arc, and the figures placed in the dimension line in the usual way. In this case it is not necessary to put the letter R (abbreviation for radius) after the dimension. In the two methods shown in Fig. 24 the R should be placed after the figures.

In putting dimensions on a drawing, the figures should be placed to read from only two sides of the paper, usually from the bottom for dimension lines which are horizontal, as the $2\frac{1}{2}''$ dimension in Fig. 20, and from the right hand for dimension lines which are vertical, as the $2\frac{1}{4}''$ dimension in the same figure. Dimensions should never be placed on center lines if it can be avoided.

If a dimension is given in one view of an object, the same dimension need not be repeated in the other views.

In putting on fractions it is better to have the line which

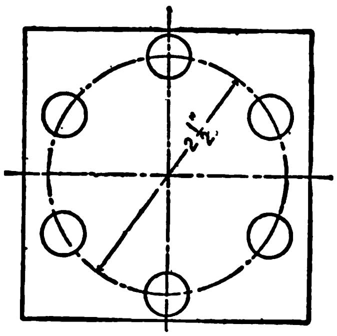



Fig. 21.

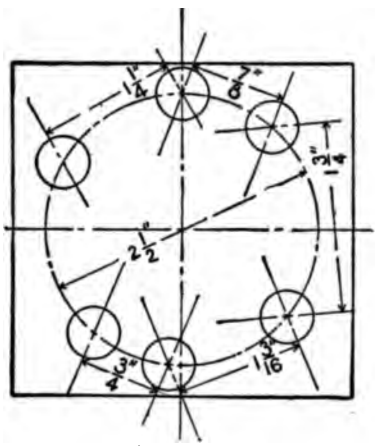
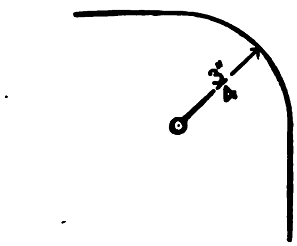


Fig. 22.

divides the numerator and denominator of the fraction extend in the same direction as the dimension line rather than at an angle; that is, the fraction would appear thus, $\frac{1}{2}$, rather than $^1/_2$.

**Finished Surfaces.** Since a working drawing is not only to



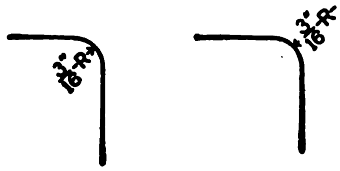



Fig. 23. Fig. 24.

show the shape and size of the object which it represents, but is to describe it completely, it is essential that there should be some means of distinguishing between the surfaces of the object which are to be left rough as they come from the forge or from the foundry, and the surfaces which are to be finished. Any surface which has been smoothed off in a lathe, planer, or any machine tool, or has been filed or scraped, is called a finished surface, and is indicated on a drawing by a letter placed on the *edge view* of this surface. In Fig. 19 the whole of the cylindrical part is finished, also the top of the rectangular part. The holes are also finished. The student should notice carefully how the finish marks are used to indicate this fact.

If a piece is to be finished all over, it should be marked "*f* all over." If it is desired to specify what kind of finish is to be put on a surface, that is, whether rough turned, smooth turned, filed, scraped, etc., a note may be made to that effect.

On some conspicuous place on the drawing the words "*f* means finish" should be printed, so that there may be no misunderstanding on the part of a person examining the drawing.

**Material.** The material of which the piece is to be made should be indicated plainly. If any part of the drawing is a cross-section, the crosshatching might show the material, provided that in some conspicuous part of the drawing a sample of the crosshatching is shown and the material which it represents is stated. It is better, however, to mark on or near each piece, in plain letters, the material of which it is to be made.

**Conventional Methods.** In drafting, as in many other kinds of work, all unnecessary labor should be avoided. The drawing should give the instructions clearly, but need not be so elaborate as to require unnecessary time in the execution. It frequently happens that if an exact drawing were made representing every line of the object, a great deal of time would be required. Accordingly, if there is any way of representing an object by a few lines only, without sacrificing clearness, it should be used. There are many details such as screw threads, springs, bolts, etc., which occur so frequently on nearly all drawings that easy methods of representation have been universally adopted. In some cases, these ways of representing objects are approximations of the exact drawings and in other cases they are not. Such methods are called conventional methods, or conventions. For some details there is more than one convention, but the same convention should not be used f[illegible]ld several objects of the same kind on the same drawing be represented conventionally by two different methods.

**Screw Threads.** The exact drawing of screw threads is a difficult part of mechanical drawing, but enough attention will be given it here to enable the student to make a simple working drawing which includes threads. The common conventional way of drawing a thread is shown in Figs. 25, 26 and 27, Fig. 25 being a single right-hand thread, and Fig. 26 a double right-hand thread.

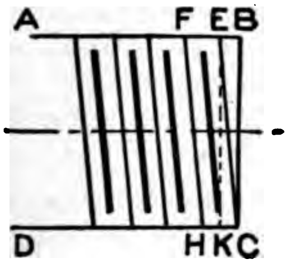


Fig. 25.

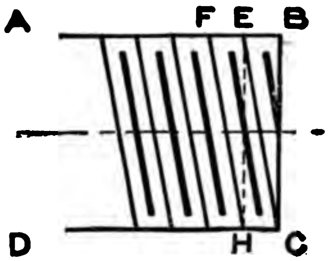


Fig. 26.

First, the plain cylindrical piece ABCD is drawn as if there were no threads upon it. The thread is then indicated by the lines EC, FH, etc., with the shorter and heavier lines between. The lighter lines are all parallel and the same distance apart. This distance is not necessarily the same as the actual pitch of the thread on the screw itself, but is usually $\frac{3}{32}$ inch or $\frac{1}{8}$ inch on drawings of common sizes of bolts. The heavy lines are parallel to the lighter ones and midway between them. The angle which the lines make with the center line of the screw depends on the distance apart of the lines, the slant being such that for a single thread, Fig. 25, a line perpendicular to the center line through one end of one of the lighter lines, as E, will strike the opposite contour of the screw DC, at a point K, which is half way between C and H. To draw the lines so that they will have this slant, choose the distance FE, which is to represent the pitch, and space it off on either of the contour lines, as AB, starting anywhere (in the figure the starting point E is one-half of the distance FE away from B). Next, draw EK per-

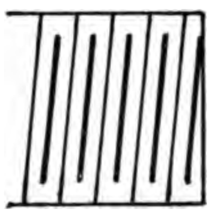


Fig. 27.

pendicular to the center line, thus finding point K, and start the spacing on the contour CD at a distance either side of K equal to $\frac{1}{2}$ FE.

The lighter lines can thus be drawn and the heavy lines put in parallel and half way between. The heavy lines should be a little shorter than the others, and, for the sake of neatness, all should be of the same length. The double thread, Fig. 26, is drawn similarly to the single thread, except that the slant is such that the perpendicular through E will pass through H.

After a little practice the student can draw the threads in this way with his triangles, getting the proper slant and the angle spacing by eye, without the necessity of measuring; he should practice with this end in view, for threads occur so frequently on drawings that the draftsman must be able to draw them rapidly.

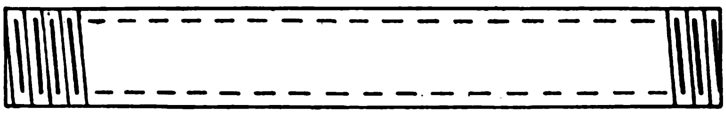


Fig. 28.

Notice should be taken of the fact that if the page be held so that the center lines of the screws in Figs. 25 and 26 are vertical, the lines which represent the threads slant downward from right to left. If the thread is left-handed the lines slant from left to right, as in Fig. 27.

In case of a long screw a few threads may be represented at each end and dotted lines carried the rest of the way, as in Fig. 28.

On any drawing of a screw which is intended for a working drawing, the pitch of the thread, or more commonly the number of threads for an inch of length should be specified; when the thread be standard, it is not always necessary to specify. Even in that case it is well to state the fact that the thread is standard. In giving the number of threads per inch it may be abbreviated, thus 12 THDS, or 12 TH. Examples of this will occur in what follows.

**Threaded Holes and Invisible Threads.** Fig. 29 shows a piece with a threaded hole in it. The hole is represented in the side view by the four parallel dotted lines. The distance apart of the two outer lines is equal to the diameter of the piece which is to be screwed into the hole. The inner lines are at a distance from the outer approximately equal to the depth of the thread. In the plan view of the piece (that is, the view looking at the end of the hole) the hole is shown by a full circle of a diameter equal to the distance apart of the inner dotted lines of the other view, and around this full circle a dotted circle whose diameter is equal to the diameter of the bolt; or, in other words, equal to the distance apart of the outer dotted straight lines. The dimension might be given on either view. In the figure it is given on the side view. In giving the diameter of a threaded hole, the diameter of the piece which is to be screwed into the hole is always given. In Fig. 29, the number of threads per inch is not stated, and in this case it would be understood to be standard. Fig. 30 shows another way of dimensioning a tapped hole, which is satisfactory and convenient.

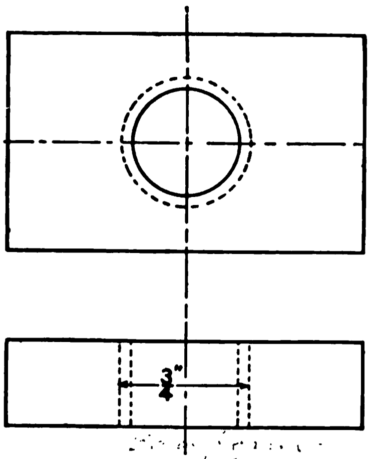


Fig. 29.

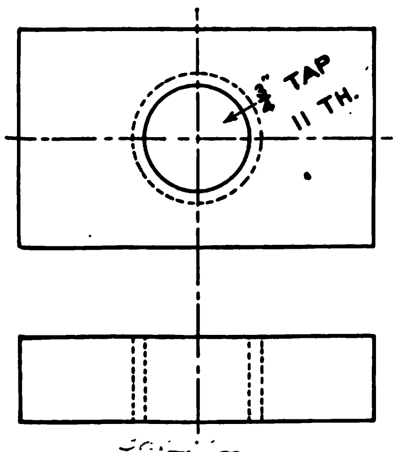


Fig. 30.

Fig. 31 shows the side view of the same piece as Fig. 29, with a part of the screw inserted in the hole. Attention is called to the fact that where the screw is hidden as it goes through the hole the thread is not shown, the parallel dotted lines representing the thread in the same manner as when the hole had no screw in it. Another point to be noted is that the cross-hatching of the broken ends for wrought iron is similar to the representation of the screw thread and one must learn to judge when the light and heavy lines mean a thread and when they are cross-hatching.

**Threads in Sectional Pieces.** Figs. 32, 33 and 34 illustrate the common method of representing threads when they occur on pieces which are drawn in cross-section. Fig. 32 is the same piece as Fig. 29, shown cross-sectioned. The front half of the piece is supposed to be removed and we are looking at the back half. Now the thread on the back side of a screw slants the opposite way from what it does on the front side, and of course the same is true of the thread in a tapped hole. Consequently, since it is the back side of the hole which is seen, the slant of the lines which represent the thread is opposite to the direction they would have were we looking at the front side of the screw which goes into the hole. We have just learned that for a right-handed thread on a screw the lines slant downward from right to left, and therefore for a right-handed thread seen on the back side of a tapped hole, the lines will slant downward from left to right. In other words, for a right-handed thread in a hole which comes in a cross-section, the lines slant the same as they would on the front of a left-hand thread on a bolt; and for a left-hand thread in a sectioned hole, he slant is the same as for a right-hand thread on a bolt.

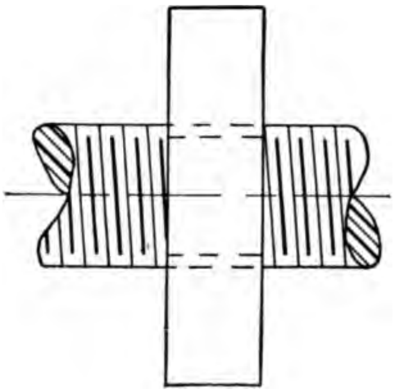


Fig. 31.

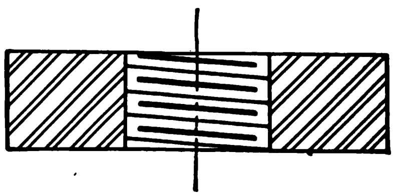


Fig. 32.

Fig. 33 is a piece which has a smooth hole through it and a thread on the outside. Here the entire thread is invisible, except at the contour of the cylinder, and must be indicated by the notches. These are drawn by spacing off the distance which is used for the pitch and from the points thus found drawing lines with the triangle which make an angle of 60 degrees with the axis of the cylinder. For a single thread the notches on one side have their outer points opposite the inner points of the notches on the other side. For a double thread the notches are directly opposite each other.

Fig. 34 shows two ways of quarter-sectioning a threaded piece, the only difference being that on one the contour of the sectional part is drawn a straight line, while on the other the contour is notched. Either one may be used. The straight contour can, of course, be drawn much more quickly and in places where there is no danger of sacrificing clearness it should be used for that reason. If the drawing is somewhat complicated, so that without the notches it might not be quite clear that the piece was threaded, the notches should be used.

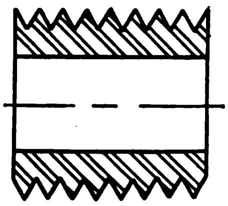


Fig. 33.

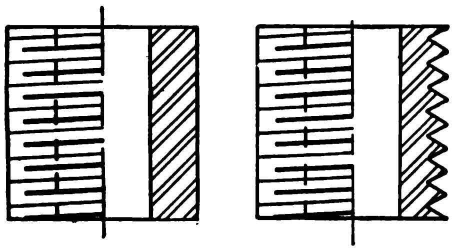


Fig. 34.

As has already been suggested, the student will doubtless find many other customs in the matter of drawing threads which are quite as good as the above. These have been given as ones which are common, and easily drawn. As a matter of convenience the following tables are given, which show the number of threads per inch on some of the most common sizes of bolts, according to the standard adopted by the United States Government, and the Whitworth or English standard.

**UNITED STATES STANDARD SCREW THREADS.**

| Diameter of Bolt. | Threads per Inch. | Diameter of Bolt. | Threads per Inch. | Diameter of Bolt. | Threads per Inch. |
|---|---|---|---|---|---|
| $\frac{1}{4}$ | 20 | $\frac{5}{8}$ | 11 | $1\frac{3}{8}$ | 6 |
| $\frac{5}{16}$ | 18 | $\frac{3}{4}$ | 10 | $1\frac{1}{2}$ | 6 |
| $\frac{3}{8}$ | 16 | $\frac{7}{8}$ | 9 | $1\frac{5}{8}$ | $5\frac{1}{2}$ |
| $\frac{7}{16}$ | 14 | 1 | 8 | $1\frac{3}{4}$ | 5 |
| $\frac{1}{2}$ | 13 | $1\frac{1}{8}$ | 7 | $1\frac{7}{8}$ | 5 |
| $\frac{9}{16}$ | 12 | $1\frac{1}{4}$ | 7 | 2 | $4\frac{1}{2}$ |

**WHITWORTH STANDARD SCREW THREADS.**

| Diameter of Bolt. | Threads per Inch. | Diameter of Bolt. | Threads per Inch. | Diameter of Bolt. | Threads per Inch. |
|---|---|---|---|---|---|
| $\frac{1}{4}$ | 20 | $\frac{5}{8}$ | 11 | $1\frac{3}{8}$ | 6 |
| $\frac{5}{16}$ | 18 | $\frac{3}{4}$ | 10 | $1\frac{1}{2}$ | 6 |
| $\frac{3}{8}$ | 16 | $\frac{7}{8}$ | 9 | $1\frac{5}{8}$ | 5 |
| $\frac{7}{16}$ | 14 | 1 | 8 | $1\frac{3}{4}$ | 5 |
| $\frac{1}{2}$ | 12 | $1\frac{1}{8}$ | 7 | $1\frac{7}{8}$ | $4\frac{1}{2}$ |
| $\frac{9}{16}$ | 12 | $1\frac{1}{4}$ | 7 | 2 | $4\frac{1}{2}$ |

**Bolts and Nuts.** Among the most common pieces of machinery are bolts and nuts, and the draftsman has frequent occasion to draw them. Fig. 35 is a conventional drawing of a $\frac{1}{2}$-inch bolt with a hexagonal head and nut. This figure shows the dimensions necessary to be given in order that a workman shall be able to make the bolt from the drawing.

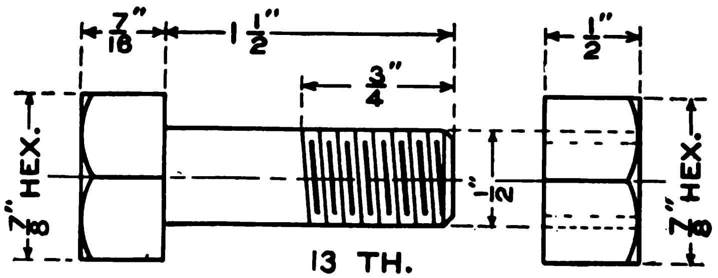



Fig. 35.

Beginning with the head of the bolt, let us study the various parts of this drawing in detail. The head is a hexagonal prism the end of which has been chamfered. We might expect that two views of the head would be necessary to completely define its shape, but the letters HEX printed after the dimension for the diameter of the head indicates that it is hexagonal. In like manner, if the head were square the letters SQ would be placed after the dimension. If two views were drawn, they would appear as in Fig. 36 The head is drawn as if the tool which cut the chamfer, cut off just the corners of the top, so as to make the top a circle tangent to the sides of the hexagon at B, E, G, etc.; the parts BCE, EFG, etc.. being portions of [illegible] sphere according to the manner of cha[illegible] EF are tangent to the line

GK in the side view, and the lines AJ, CD, and FH are all equal in length. The curves ABC and CEF are properly the lines of intersection of a cone or sphere, as the case may be, with the hexagonal prism, but a convenient and sufficiently accurate way of drawing them is by arcs of circles with the center on the line HJ, half way between HD and DJ, as indicated. The chamfer is represented in the end view by a circle inscribed in the hexagon.

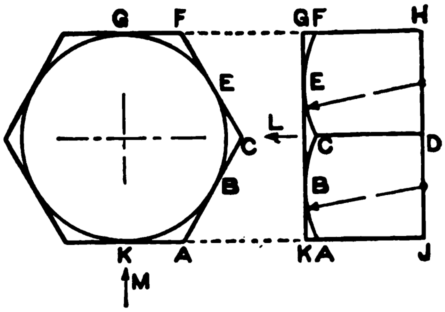


Fig. 36.

It will be noticed that in Fig. 35 that view of the head is given which shows two faces of the prism, so that the shortest dimension of the hexagon is given. That is, the view is taken in the direction of the arrow L, Fig. 36, instead of in the direction of the arrow M.

This rule should be followed on all detail drawings. The case when it is desirable to give a view in the direction of the arrow M will be discussed later.

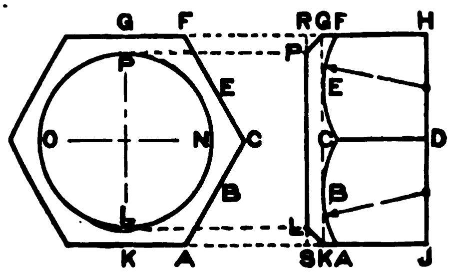


Fig. 37.

Sometimes it is desired to represent the chamfer as being greater, as in Fig. 37. To do this, draw the end view of the hexagon and inside it, of a diameter as much smaller as desired, draw the circle PNLO. Next draw the side view of the hexagonal prism as if there were no chamfer, as shown at the right (partly in dotted lines). Then from P and L, the upper and lower points of the circle in the other view, draw lines perpendicular to RS and meeting it at P and L. From P and L draw PG and LK, either at an angle of 45 degrees or 30 degrees (the latter being preferable) with RS, and meeting the lines RH and SJ at G and K. Join G and K by a construction line GK (shown dotted but not to be left in the tangent to this line with radius B equal to one-half of A. The lines EF are then drawn as explained for Fig. 41.

Referring again to Fig. 35, the dimension which shows the length of the bolt under the head should be given to the extreme point of the bolt, as should also the dimension which shows how much of the bolt is threaded.

Most of the bolts in common use are made of standard sizes, that is, for a certain diameter of bolt there is a corresponding standard diameter and thickness for the head and the nut, and a standard number of threads per inch, so that if the bolt which the

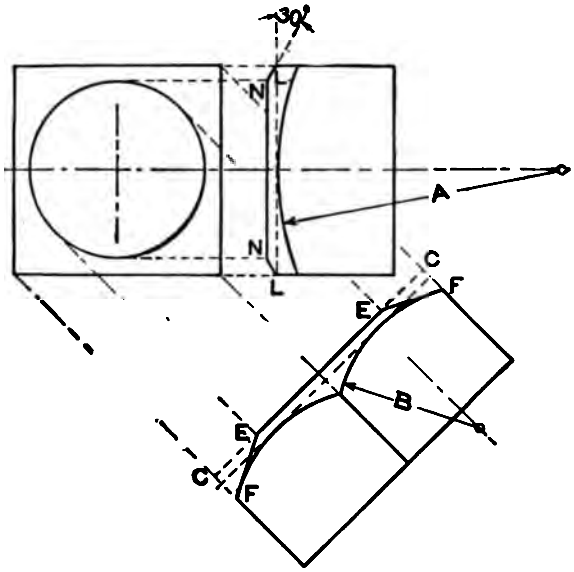



Fig. 42.

draftsman wishes to use has these standard dimensions they may be omitted from the drawing and a note made that the bolt is standard. Then the only dimensions necessary to be given are the diameter, the length under the head, and the length of the threaded part.

The following tables give the United States standard sizes of square and hexagonal heads and nuts for bolts. The columns headed "Width of Nut" and "Width of Head" give the shortest dimension of the square or hexagon, that is, the diameter of the inscribed circle. The standard number of threads per inch can be found from the table already given.

## SQUARE BOLT HEADS. U. S. STANDARD (Franklin Institute).

| Dia. of Bolt. | Width of Head. | Thickness of Head. | Dia. of Bolt. | Width of Head. | Thickness af Head. |
|---|---|---|---|---|---|
| 1/4 | 1/2 | 1/4 | 1 | 1 5/8 | 13/16 |
| 5/16 | 19/32 | 19/64 | 1 1/8 | 1 13/16 | 29/64 |
| 3/8 | 11/16 | 11/32 | 1 1/4 | 2 | 1 |
| 7/16 | 25/32 | 25/64 | 1 3/8 | 2 3/16 | 1 3/32 |
| 1/2 | 7/8 | 7/16 | 1 1/2 | 2 3/8 | 1 3/16 |
| 9/16 | 31/32 | 31/64 | 1 5/8 | 2 9/16 | 1 9/32 |
| 5/8 | 1 1/16 | 17/32 | 1 3/4 | 2 3/4 | 1 3/8 |
| 3/4 | 1 1/4 | 5/8 | 1 7/8 | 2 15/16 | 1 15/32 |
| 7/8 | 1 7/16 | 23/32 | 2 | 3 1/8 | 1 9/16 |

## HEXAGON BOLT HEADS. U. S. STANDARD (Franklin Institute).

| Dia. of Bolt. | Width of Head. | Thickness of Head. | Dia. of Bolt. | Width of Head. | Thickness of Head. |
|---|---|---|---|---|---|
| 1/4 | 1/2 | 1/4 | 1 | 1 5/8 | 13/16 |
| 5/16 | 19/32 | 19/64 | 1 1/8 | 1 13/16 | 29/64 |
| 3/8 | 11/16 | 11/32 | 1 1/4 | 2 | 1 |
| 7/16 | 25/32 | 25/64 | 1 3/8 | 2 3/16 | 1 3/32 |
| 1/2 | 7/8 | 7/16 | 1 1/2 | 2 3/8 | 1 3/16 |
| 9/16 | 31/32 | 31/64 | 1 5/8 | 2 9/16 | 1 9/32 |
| 5/8 | 1 1/16 | 17/32 | 1 3/4 | 2 3/4 | 1 3/8 |
| 3/4 | 1 1/4 | 5/8 | 1 7/8 | 2 15/16 | 1 15/32 |
| 7/8 | 1 7/16 | 23/32 | 2 | 3 1/8 | 1 9/16 |

## SQUARE AND HEXAGON NUTS. U. S. STANDARD (Franklin Institute).

| Dia. of Bolt. | Width of Nut. | Thickness of Nut. | Dia. of Bolt. | Width of Nut. | Thickness of Nut. |
|---|---|---|---|---|---|
| 1/4 | 1/2 | 1/4 | 1 | 1 5/8 | 1 |
| 5/16 | 19/32 | 5/16 | 1 1/8 | 1 13/16 | 1 1/8 |
| 3/8 | 11/16 | 3/8 | 1 1/4 | 2 | 1 1/4 |
| 7/16 | 25/32 | 7/16 | 1 3/8 | 2 3/16 | 1 3/8 |
| 1/2 | 7/8 | 1/2 | 1 1/2 | 2 3/8 | 1 1/2 |
| 9/16 | 31/32 | 9/16 | 1 5/8 | 2 9/16 | 1 5/8 |
| 5/8 | 1 1/16 | 5/8 | 1 3/4 | 2 3/4 | 1 3/4 |
| 3/4 | 1 1/4 | 3/4 | 1 7/8 | 2 15/16 | 1 7/8 |
| 7/8 | 1 7/16 | 7/8 | 2 | 3 1/8 | 2 |

**Pipes and Pipe Threads.** The various kinds of pipe in common use are made to standard sizes, and as the draftsman very often comes in contact with piping we will consider it briefly. The kinds most often used are wrought-iron or steel pipe, brass pipe made to the size of wrought-iron pipe, and cast-iron pipe. The cast-iron pipe is made of different weights and form, according to the purpose for which it is to be used. Standard weight iron pipe is rated by its nominal inside diameter, although the actual diameter does not in most cases quite agree with the nominal diameter. A $\frac{1}{4}$-inch pipe is a pipe, the hole in which is supposed to be $\frac{1}{4}$ inch in diameter, but if carefully measured it will be found to be a few hundredths of an inch larger.

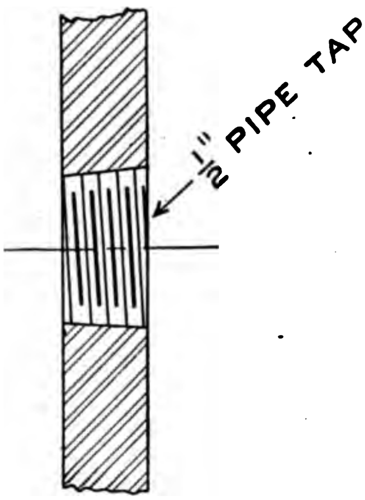


Fig. 43.

The threads on pipes and pipe fittings are also made to standard; taps and dies are made for various sizes of pipe. These taps and dies are spoken of or described by stating the size of the pipe for which they are intended For example, a $\frac{1}{4}$-inch pipe-tap is a tap of the proper size, shape, and number of threads per inch to cut the thread in a hole to receive a $\frac{1}{4}$-inch pipe. Threaded holes are made tapering for pipes, the standard taper being $\frac{3}{4}$ inch per foot, that is, the diameter of the hole decreases at the rate of $\frac{3}{4}$ inch per foot. In representing a hole which is threaded with a pipe tap, the hole is drawn of a diameter at its larger end about equal to the outside diameter of the pipe which is to be screwed into it, and is drawn tapering. It is well to make the taper considerably greater than the actual taper, so that the person looking at the drawing may see at a glance that the hole is for a pipe.

The thread is indicated in one of the conventional ways previously explained, but the number of threads per inch and the diameter of the hole need not be given; instead, a note is made that the hole is tapped for a certain size pipe. Fig. 43 illustrates this.

The following tables of standards for wrought-iron pipe may be found convenient:

**STANDARD SIZES OF WROUGHT IRON PIPE.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nominal Size. | 1/8 | 1/4 | 3/8 | 1/2 | 3/4 | 1 | 1¼ | 1½ | 2 |
| Actual Inside Diameter. | .27 | .364 | .494 | .623 | .824 | 1.048 | 1.38 | 1.611 | 2.067 |
| Outside Diameter. | .405 | .54 | .675 | .84 | 1.05 | 1.315 | 1.66 | 1.90 | 2.375 |
| Nominal Size. | 2½ | 3 | 3½ | 4 | 4½ | 5 | 6 | 7 | 8 |
| Actual Inside Diameter. | 2.468 | 3.067 | 3.548 | 4.026 | 4.508 | 5.045 | 6.065 | 7.023 | 7.982 |
| Outside Diameter. | 2.875 | 3.50 | 4.00 | 4.50 | 5.00 | 5.563 | 6.625 | 7.625 | 8.625 |

**STANDARD THREADS FOR WROUGHT IRON PIPE.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nominal Size of Pipe. | 1/8 | 1/4 | 3/8 | 1/2 | 3/4 | 1 | 1¼ | 1½ | 2 |
| Threads per Inch. | 27 | 18 | 18 | 14 | 14 | 11½ | 11½ | 11½ | 11½ |
| Nominal Size of Pipe. | 2½ | 3 | 3½ | 4 | 4½ | 5 | 5½ | 7 | 8 |
| Threads per Inch. | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |

**Scale Drawings.** When the object which is to be drawn is not so large but that it can be easily actual size, or full size as it is called, on a sheet of paper which is of convenient dimensions, it is well, usually, to draw the piece full size. In most cases, however, the machine, or the building, or whatever is to be drawn is so large that it would be impossible to draw it full size. Then the drawing is made to some reduced scale, that is, all the dimensions are drawn smaller than the actual dimensions of the object itself; all dimensions being reduced in the same proportion. For example, if a piece is to be drawn half size, the distance from one point to another on the drawing would be one-half what it is on the piece itself; if the drawing is one-fourth size, the distance on the drawing would be one-fourth what it is on the piece itself, and so on. In dimensioning such a drawing the dimension which is written on tho drawing is the *actual dimension* of the piece, and not the distance which is measured on the drawing. This fact must be very clearly understood by the student.

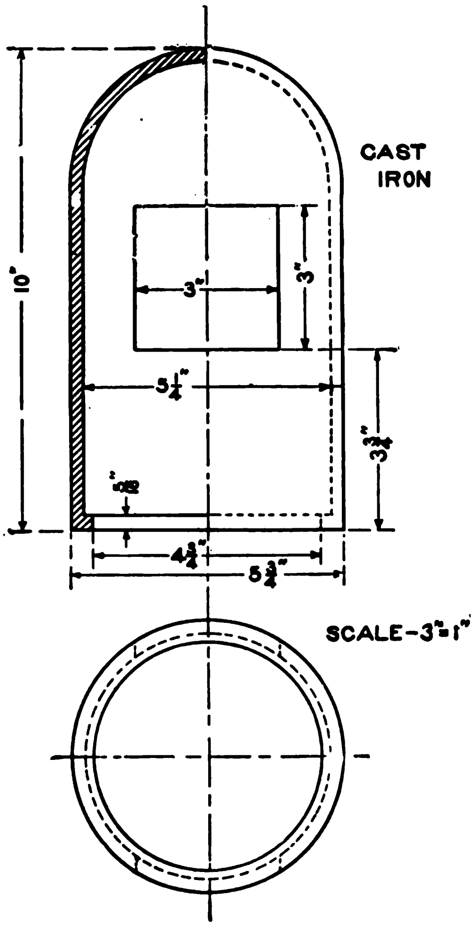



Fig. 44.

The common method of reducing all the dimensions in the same proportion is to choose a certain distance and let that distance represent one foot, this distance is then divided into twelve parts and each one of these parts represents an inch; then if half and quarter inches are required these twelfths are subdivided into halves, quarters, etc., until the subdivisions become so small that they cannot be used. We now have a scale which represents the common foot rule with its subdivisions into inches and fractions; but our new foot is smaller than the ordinary distance which we call a foot, and of course its subdivisions are proportionately smaller. When we make a measurement on the drawing we make it with our reduced foot rule and when we make a measurement on the machine itself we make it with the common foot rule.

Draftsmen's scales can be bought which have different distances thus divided, so that if the draftsman wishes to draw a piece one-fourth size he looks over his scale until he finds a distance of three inches (which is of course one-fourth of a foot) divided as explained above, and he uses this to measure with on his drawing. His drawing would then be made to a scale of three inches to the foot. In the same way, if he wishes to make his drawing one-twelfth size he finds on his scale one inch divided into twelfths and fractions of twelfths and uses this as his standard of measurement; if he wishes to make his drawing one forty-eighth size he uses a quarter inch with its subdivisions. Sometimes if the piece to be drawn is very small, the drawing is made at an enlarged scale, such as twice size, three times size, etc.

The mistake of choosing the wrong distance to use on a scale is often made. For example, if he wishes to draw a piece $\frac{1}{4}$ size, he will look over his scale for a place marked $\frac{1}{4}$, and use this for his standard for $\frac{1}{4}$ size, which is wrong. The figure on the scale indicates the distance which is divided up to represent one foot, so

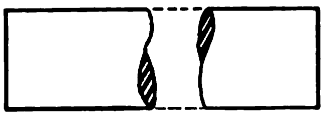


Fig. 45.

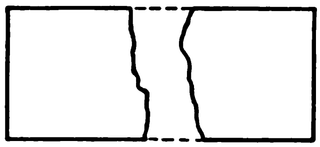


Fig. 46.

that the part of the scale which has $\frac{1}{4}$ marked on it means that $\frac{1}{4}$ of an inch is divided up into twelfths, or in other words, if a drawing is made according to that scale it will be $\frac{1}{48}$th size.

Every drawing which is made at any other scale than full size should have the scale marked on it plainly.

Fig. 44 shows a piece drawn to a scale of 3 inches per foot, that is, $\frac{1}{4}$ size.

**Long Pieces.** A piece which is very long in proportion to its diameter or width is often difficult to draw complete, especially if there is much detail to any part of it, for if the scale is made so small that the length will go on a sheet of paper of convenient size the small part is so reduced that it is very small. If such a piece is plain the whole or part of its length, a portion of the plain part may be broken out on the drawing thus shortening the drawing of the piece so that a larger scale may be used. Of course in giving the dimension for the length, the *actual* length must be given. Fig. 45 shows a round piece thus broken out and Fig. 46 a rectangular piece.

It is a good idea to connect by dotted lines the two parts thus broken, although this is not essential.

**"Turning Up" a Section.** Sometimes a second view of a piece may be avoided by drawing on the first view a partial view showing the shape of the cross-section at the place where drawn. This partial view or "turned-up section" may be drawn in either full or dotted lines and should be cross hatched. If it comes where there are other lines of the original view, as is usually the case, the original lines would be drawn in regardless of the fact that they conflicted with the auxiliary view. Fig. 47 is an illustration.

**In General.** A working drawing will usually belong to one of the three following classes: *first*, a design of an entirely new machine; *second*, a drawing of a machine which is already built; *third*, a drawing of a new part to fit a machine which is already built, or a drawing of an old machine remodelled.

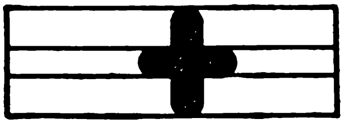


Fig. 47.

In order to design a new machine, or a part of a machine, the draftsman must understand the principles of drawing and must also have a clear understanding of the work which the machine is to perform, and must know something of the principles of machine design and the strength of materials. A study of the general manner of proceeding with the drawing, when these things are known, will come later in this course. The draftsman may make a drawing of a machine which is already built, even if he has no understanding of the working of the machine, although under such conditions he works at a great disadvantage. In any case, he must know the principles of drawing.

If the student has learned thoroughly what has preceded in this course, he should be ready to take up the drawing from a machine, and we will now consider the general system to be followed in making such a drawing.

**Sketches.** In most cases it would be inconvenient for the draftsman to take his drawing board and instruments to the machine and make his careful drawing with the machine close at hand; preferably, he makes what are called sketches, carries his sketches to the drafting room and makes his drawing from them. In making the sketches, each piece of the machine should be taken separately and a complete working drawing made of it, the only difference between these sketches and the finished drawing being that it is made largely without the use of instruments, triangles, etc.; that is, it is made free hand. The experienced draftsman will draw some lines and circles free hand, and use his instruments on some, according as he may think that he will save time by doing the one or the other; but it is well for the beginner to gain practice by making the sketches, almost wholly free hand, except large circles, and long lines.

The sketches should be neat and perfectly clear, so that if they are laid aside for a long time they can be clearly understood without depending at all upon memory. There is a strong tendency for the beginner to make his sketches hurriedly, thinking that when he comes to finish his drawing he can supply the details from memory. This is a bad plan and will lead to many mistakes. The sketches must be so clear and complete that anyone can read them who has never seen the machine. No attempt need be made to draw them to scale, but **all dimensions**, carefully measured from the machine, should be placed on the sketch.

After every piece of the machine has been thus sketched separately, it is well to make a rough, general sketch of the whole machine, to show how the various pieces fit together, a few of the most important over-all dimensions, distances between centers, etc.

All sketching should be done as rapidly as possible without sacrificing clearness. Before starting to sketch a piece, the draftsman must decide what views are necessary to describe the piece clearly. All sketches should be made large to avoid confusion.

**Detail Drawing.** After the sketches are made, the next step is the making of the pencil drawing from the sketches, accurately to scale. The size of the plate on which the drawing is to be made is usually fixed by some standard. Where many drawings are made and kept in an office, it is desirable to keep the plates of uniform size, as far as possible. It is good practice to have two or three standard sizes of plates, one for small drawings, one for ordinary-sized work, and one for large drawings; then, whenever a drawing is made, make it on one of these standard plates.

Assuming, then, that we have our paper stretched on the drawing board and the plate laid out, the next step will be to arrange the drawings of the various pieces on the plate so that there will be room for all and so that they may be properly placed with relation to each other. It may happen that there will not be room on one plate for all the pieces, but that two or more plates will be required. When the parts must be thus arranged on different plates, an effort should be made to keep on the same plate those parts which belong together. For example, if we were drawing a lathe, the details of the parts of the head stock might form one plate, the apron another, and so on.

In locating the various pieces on a plate, they should be placed as nearly as possible in the same relative position to each other that they bear in the machine, except that they are separated. For example: if a nut belongs on the end of a screw, it is desirable to draw it on the same center line with the screw and at the end where it belongs. If a piece is vertical in the machine it should be vertical on the plate, and if horizontal in the machine, it should be horizontal on the plate.

The approximate location of the pieces on the plate may be easily decided by taking a small sheet of paper of about the same proportion as the plate, but perhaps one-fourth or one-half size, and sketching on it roughly the outline of the various pieces. The arranging of the plate should not be allowed to take much time, but should be done as rapidly as possible. After the location of each view of each piece is determined, the pencil drawing should begin (to scale) with one of the principal pieces. In almost all cases a center line is first drawn. It is better to carry along all the views of a piece at once, instead of completing one view at a time. The piece started should have all its views finished and completely dimensioned before another piece is begun; exceptions to this are sometimes necessary for special reasons. The lines should be drawn accurately, but no attempt need be made to obtain finish; that is, in order to save time, the lines may be run past the point where they should properly stop, etc. Nothing should be omitted, however.

Each plate of details should have a title, stating of what machine it is a drawing, and, if there are several plates, it is well to state also of what part of the machine the plate in question is a drawing. It is also a good idea to print its name beside each of the principal pieces.

**Tracing.** Having finished the pencil drawing, the next step is the inking. In some offices the pencil drawing is made on a thin. tough paper, called board paper, and the inking is done over the pencil drawing, in the manner with which the student is already familiar. It is more common to do the inking on thin, transparent cloth, called tracing cloth, which is prepared for the purpose. This tracing cloth is made of various kinds, the kind in ordinary use being what is known as "dull back," that is, one side is finished and the other side is left dull. Either side may be used to draw upon, but most draftsmen prefer the dull side. If a drawing is to be traced it is a good plan to use a 3H or 4H pencil, so that the lines may be easily seen through the cloth.

The tracing cloth is stretched smoothly over the pencil drawing and a little powdered chalk rubbed over it with a dry cloth, to remove the slight amount of grease or oil from the surface and make it take the ink better. The dust must be carefully brushed or wiped off with a soft cloth, after the rubbing, or it will interfere with the inking.

The drawing is then made in ink on the tracing cloth, after the same general rules as for inking the paper, but care must be taken to draw the ink lines exactly over the pencil lines which are on the paper underneath, and which should be just heavy enough to be easily seen through the tracing cloth. The ink lines should be firm and fully as heavy as for ordinary work. In tracing, it is better to complete one view at a time, because if parts of several views are traced and the drawing left for a day or two, the cloth is liable to stretch and warp so that it will be difficult to complete the views and make the new lines fit those already drawn and at the same time conform to the pencil lines underneath. For this reason it is well, when possible, to complete a view before leaving the drawing for any length of time, although of course on views in which there is a good deal of work this cannot always be done. In this case the draftsman must manipulate his tracing cloth and instruments to make the lines fit as best he can. A skillful draftsman will have no trouble from this source, but the beginner may at first find difficulty.

Inking on tracing cloth will be found by the beginner to be quite different from inking on the paper to which he has been accustomed, and he will doubtless make many blots and think at first that it is hard to make a tracing. After a little practice, however, he will find that the tracing cloth is very satisfactory and that a good drawing can be made on it quite as easily as on paper.

The necessity for making erasures should be avoided, as far as possible, but when an erasure must be made a good ink rubber or typewriter eraser may be used. If the erased line is to have ink placed on it, such as a line crossing, it is better to use a soft rubber eraser. All moisture should be kept from the cloth.

**Blue Printing.** The tracing, of course, cannot be sent into the shop for the workmen to use, as it would soon become soiled and in time destroyed, so that it is necessary to have some cheap and rapid means of making copies from it. These copies are made by the process of blue printing in which the tracing is used in a manner similar to the use made of a negative in photography.

Almost all drafting rooms have a frame for the purpose of making blue prints. These frames are made in many styles, some simple, some elaborate. A simple and efficient form is a flat surface usually of wood, covered with padding of soft material, such as felting. To this is hinged the cover, which consists of a frame similar to a picture frame, in which is set a piece of clear glass. The whole is either mounted on a track or on some sort of a swinging arm, so that it may readily be run in and out of a window.

The print is made on paper prepared for the purpose by having one of its surfaces coated with chemicals which are sensitive to sunlight. This coated paper, or blue-print paper, as it is called, is laid on the padded surface of the frame with its coated side uppermost; the tracing laid over it right side up, and the glass pressed down firmly and fastened in place. Springs are frequently used to keep the paper, tracing, etc., against the glass. With some frames it is more convenient to turn them over and remove the backs. In such cases the tracing is laid against the glass, face down; the coated paper is then placed on it with the coated side against the tracing cloth.

The sun is allowed to shine upon the drawing for a few minutes, then the blue-print paper is taken out and thoroughly washed in clean water for several minutes and hung up to dry.

If the paper has been recently prepared and the exposure properly timed, the coated surface of the paper will now be of a clear, deep blue color, except where it was covered by the ink lines, where it will be perfectly white.

The action has been this: Before the paper was exposed to the light the coating was of a pale yellow color, and if it had then been put in water the coating would have all washed off, leaving the paper white. In other words, before being exposed to the sunlight the coating was soluble. The light penetrated the transparent tracing cloth and acted upon the chemicals of the coating, changing their nature so that they became insoluble; that is, when put in water, the coating, instead of being washed off, merely turned blue. The light could not penetrate the ink with which the lines, figures, etc., were drawn, consequently the coating under these was not acted upon and it washed off when put in water, leaving a white copy of the ink drawing on a blue background. If running water cannot be used, the paper must be washed in a sufficient number of changes until the water is clear. It is a good plan to arrange a tank having an overflow, so that the water may remain at a depth of about 6 or 8 inches.

The length of time to which a print should be exposed to the light depends upon the quality and freshness of the paper, the chemicals used and the brightness of the light. Some paper is prepared so that an exposure of one minute, or even less, in bright sunlight, will give a good print and the time ranges from this to twenty minutes or more, according to the proportions of the various chemicals in the coating. If the full strength of the sunlight does not strike the paper, as, for instance, if clouds partly cover the sun, the time of exposure must be lengthened.

**Assembly Drawing.** We have followed through the process of making a detail drawing from the sketches to the blue print ready for the workmen. Such a detail drawing or set of drawings shows the form and size of each piece, but does not show how the pieces go together and gives no idea of the machine as a whole. Consequently, a general drawing or assembly drawing must be made, which will show these things. Usually two or more views are necessary, the number depending upon the complexity of the machine. Very often a cross-section through some part of the machine, chosen so as to give the best general idea with the least amount of work, will make the drawing clearer.

The number of dimensions required on an assembly drawing depends largely upon the kind of machine. It is usually best to give the important over-all dimensions and the distance between the principal center lines. Care must be taken that the over-all dimensions agree with the sum of the dimensions of the various details. For example, suppose three pieces are bolted together, the thickness of the pieces according to the detail drawing, being one inch, two inches, and five and one-half inches respectively; the sum of these three dimensions is eight and one-half inches and the dimensions from outside on the assembly drawing, if given at all, must agree with this. It is a good plan to add these over-all dimensions, as it serves as a check and relieves the mechanic of the necessity of adding fractions.

### FORMULA FOR BLUE-PRINT SOLUTION.

Dissolve thoroughly and filter.

| | | |
|---|---|---|
| A. | Red Prussiate of potash | 2½ ounces, |
| | Water | 1 pint. |
| B. | Ammonio-Citrate of iron | 4 ounces, |
| | Water | 1 pint. |

Use equal parts of A and B.

### FORMULA FOR BLACK PRINTS.

**Negatives. White lines on blue ground;** prepare the paper with

| | |
|---|---|
| Ammonio-Citrate of iron | 40 grains, |
| Water | 1 ounce. |

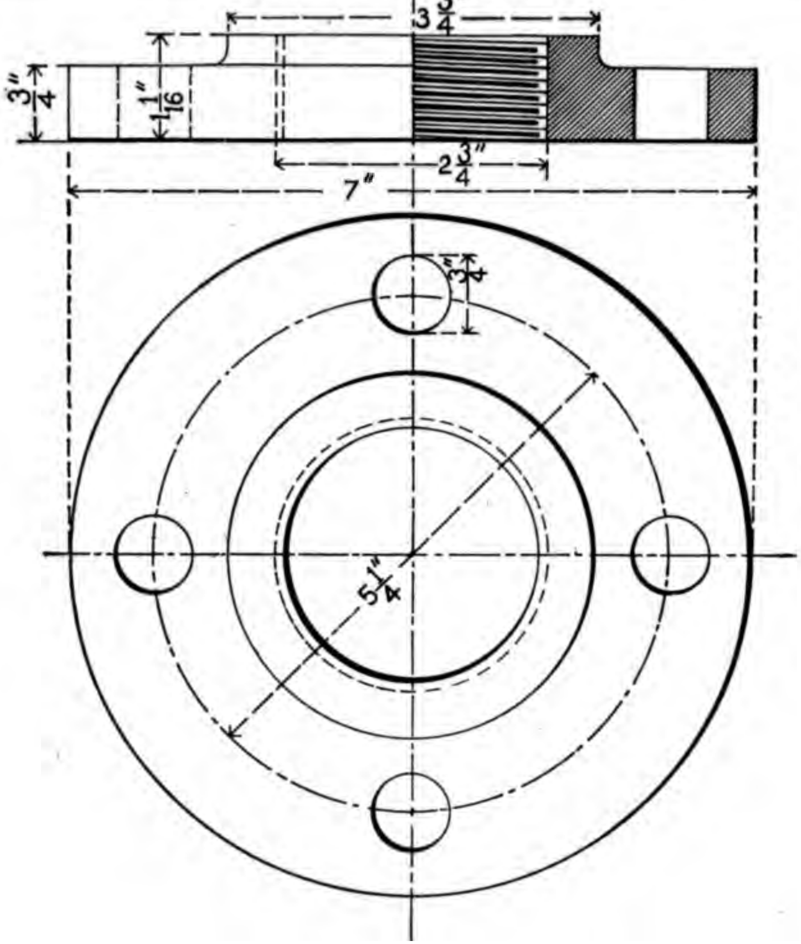
After printing wash in water.

**Positives. Black lines on white ground;** prepare the paper with:

| | |
|---|---|
| Iron perchloride | 616 grains, |
| Oxalic Acid | 308 grains, |
| Water | 14 ounces. |

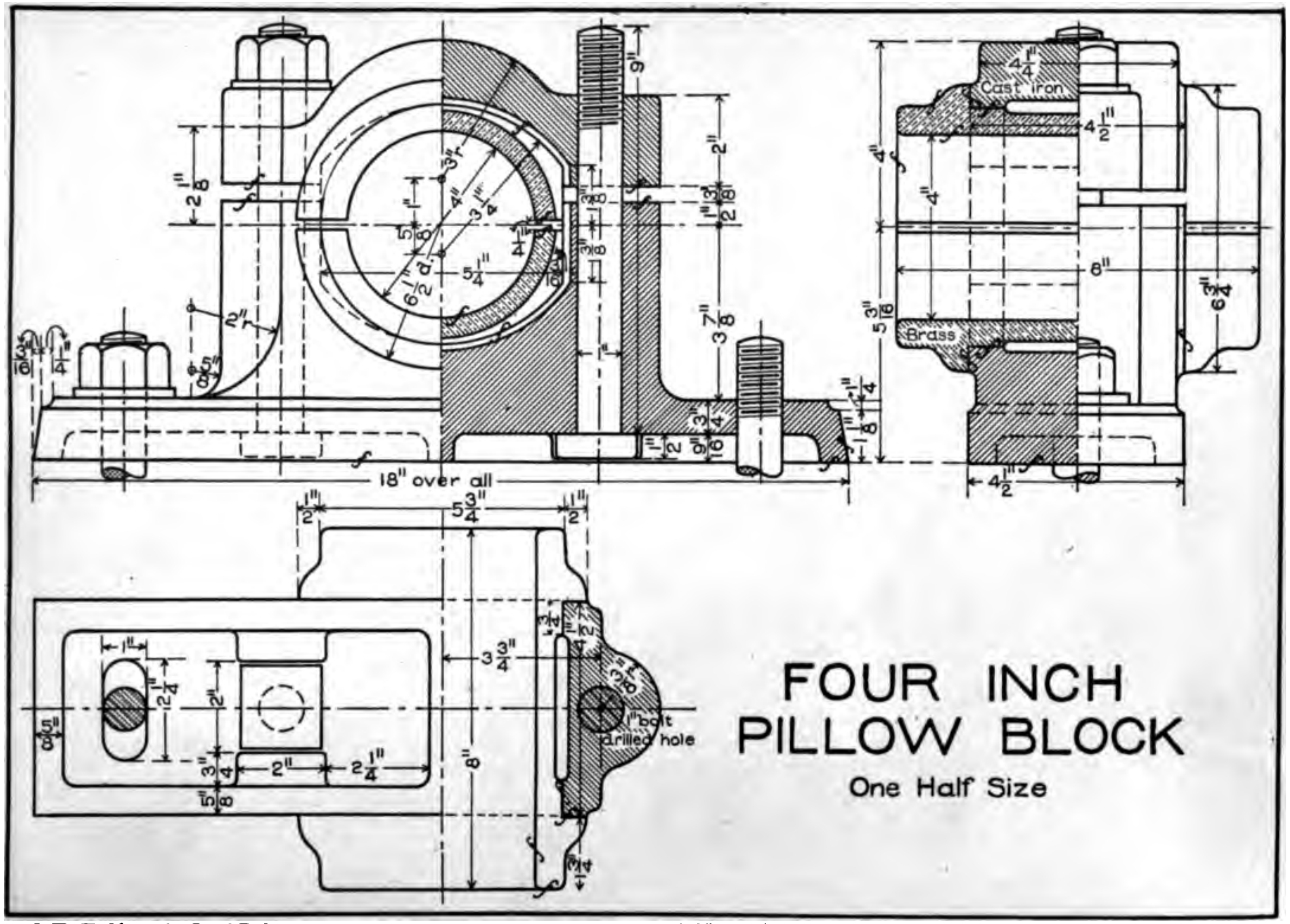
| | | |
|---|---|---|
| **Develop in** | Gallic Acid | 1 ounce, |
| | Citric Acid | 1 ounce, |
| | Alum | 8 ounces. |

Use 1¼ ounces of developer to one gallon of water. Paper is fully exposed when it has changed from yellow to white.




PIPE COUPLING

PLATE IX




APRIL 27. 1901 HERBERT CHANDLER CHICAGO ILL.

## PLATES.

### PLATE VIII.

**Pipe Coupling.** The drawing represents one of a pair of cast-iron couplings used for connecting two lengths of pipe. It is threaded for a right-handed thread, but appears left-handed because the back part of the thread is visible in the section.

The vertical center line of the coupling is in the center of the plate; the center of the plan is $3\frac{7}{8}$ inches from the lower border and the bottom of the elevation $1\frac{7}{8}$ inches from the top border line. The elevation is made in half section, that is, the right-hand half. It is made by imagining that the front right quarter of the coupling is cut away by vertical planes. If the cutting plane passes through a hole or opening the cross-hatching is omitted. The dotted lines at the left of the hole show that it is threaded. The distance between these lines is $\frac{3}{32}$ inch, the depth of the thread. The threaded or tapped portion is shown in plan by the two circles, the dotted circle representing the outside and the full circle the inside or root of the thread.

The boss or hub adds to the strength and allows more threads. The shade lines should be placed on the drawing following the custom for shop drawings. The title "Pipe Coupling" should be placed as shown and made with letters $\frac{1}{4}$ inch high. The letters may be either vertical or inclined Gothic capitals.

### PLATE IX.

**Pillow Block.** The drawings for this plate are three views—side, plan and end—of a 4 inch-pillow block. Each view is half in section. The drawing should be one-half size. Make the vertical center line of the side and plan views $4\frac{3}{4}$ inches from the left-hand border. The horizontal center line of the side view should be $2\frac{3}{8}$ inches from the top border line and the horizontal center line of the plan $2\frac{1}{4}$ inches from the bottom border line. Locate the vertical center line of the end view $2\frac{1}{4}$ inches from the right-hand border line; the horizontal center line will of course be a continuation of that of the side view. Note that the left-hand half of the plan represents what is seen by looking up from below. The cutting plane for the right-hand half passes horizontally through the center of the shaft.

The student should put on shade lines and finish marks; also the notes and dimensions. Make the letters of the title vertical Gothic capitals $\frac{3}{8}$ inch high.

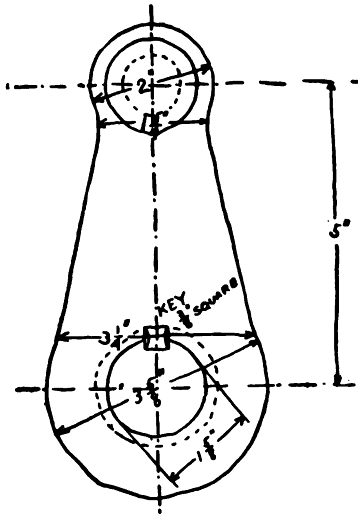


Fig. 48.

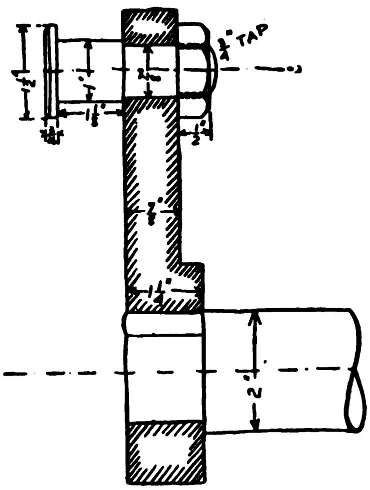


Fig. 49.

PLATE X.

**Overhung Crank.** The two drawings on this plate are to be made full size from the free-hand sketches Figs. 48 and 49. These are such as would be given the draftsman or such he would make for his own work. Place the two views so that they will look well on the plate. Put on shade lines and dimensions.

PLATE XI.

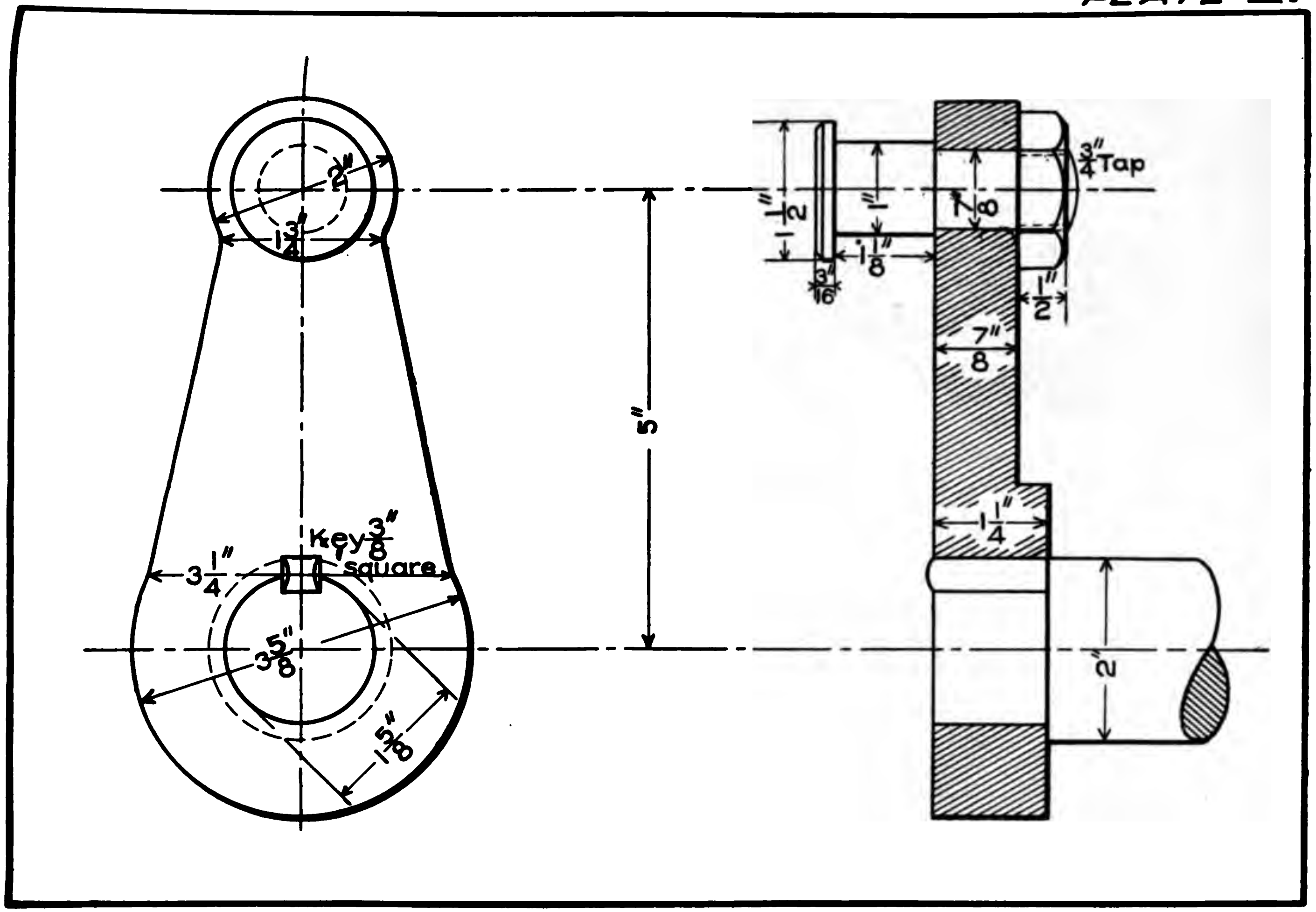
**Cylinder Head.** This plate consists of a plan view and a cross-section of the cylinder head of a small engine. The center line for the two views is drawn half way between the upper and lower border lines. Always allow sufficient space for dimensions.

The shade lines should be placed on the drawing, following the methods described for machine drawing. Locate the title and explanatory notes to make the plate appear well balanced.

PLATE XI A.

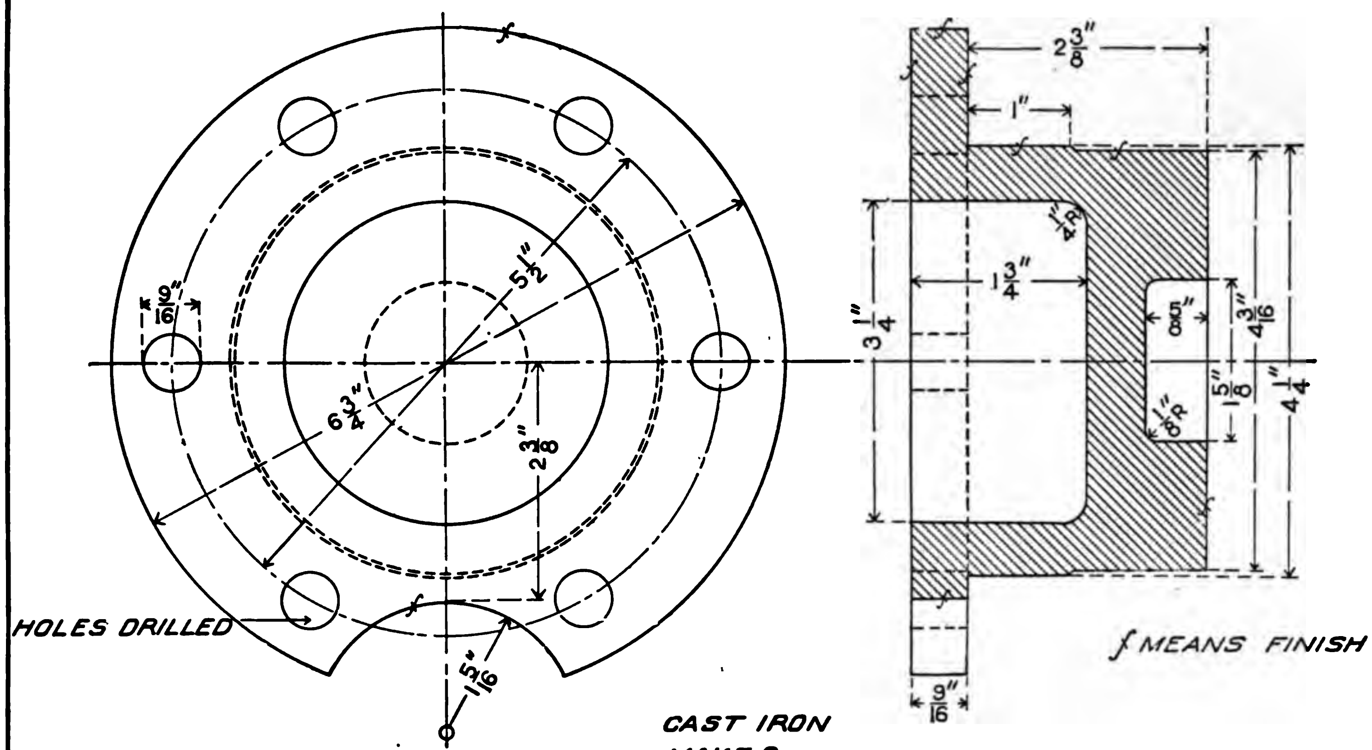
**Blue Print.** Make a tracing on tracing cloth and (optional) a blue print of one of these plates.

PLATE I.



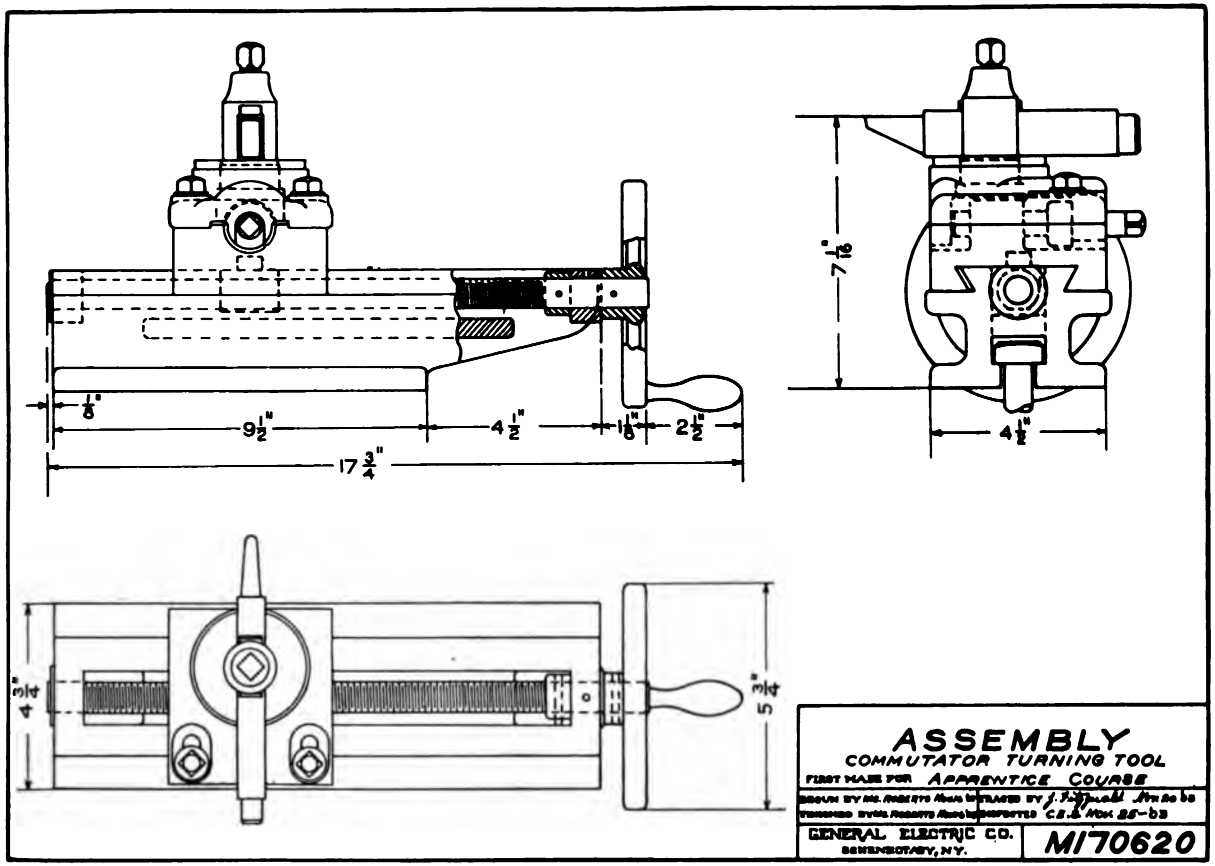

MAY 20, 1901. HERBERT CHANDLER, CHICAGO, ILL.

# CYLINDER HEAD




CAST IRON
MAKE 2

MAY 20. 1901. HERBERT CHANDLER CHICAGO, ILL.




EXAMPLE OF SHOP DRAWING MADE IN DRAFTING ROOM OF THE GENERAL ELECTRIC COMPANY.

# MECHANICAL DRAWING.

## PART IV.

### WORKING SHOP DRAWINGS.

In Parts I to III, inclusive, the fundamental principles of Mechanical Drawing are explained and illustrated. The production of working drawings has also been discussed to some extent, and the usual characters and symbols explained and applied. The elementary work already outlined has been treated chiefly from the standpoint of correctness of line representation considered by itself, without a detailed study of the use to which the drawings so produced are to be applied.

Evidently this is the proper method, for the student should gain a thorough understanding of the principles which underlie line representation before attempting to apply them to any extended practical use. In all of this preceding work it is intended that the theoretical principles shall overshadow any incidental references made to practical application, however true and pertinent the latter may be for purposes of illustration. Hence, before taking up any advanced work, the student should fully realize the importance, in fact, the absolute necessity, of thoroughly understanding the fundamental principles which have been outlined in the books which have preceded Part IV.

At this point the student must realize that a lack of proper elementary and fundamental training will make him "go lame" at every point of his course, and probably prevent the attainment of proficiency which otherwise would naturally and almost instinctively come with advanced study. It is the thorough and ready knowledge, always at his fingers' ends, of *all* the principles of Mechanical Drawing, which makes the expert draftsman.

**Plan and Scope of Advanced Work.** It is now intended to throw an entirely different light on the matter, and view the subject of Mechanical Drawing from a purely practical standpoint; viz., that of Utility. It is assumed that the student understands and can use the principles which have been previously discussed.

If in a working shop drawing we choose to modify any of these theoretical principles, it will be because of increased value in *Utility* of the drawing. For example, we may desire to omit some portions of an elevation or plan or side view of a complicated casting, because certain details will thus be more clearly brought out. We may make a "zigzag" section to show construction which, by absolute fidelity to theoretical principle, would be confused, or hidden in a maze of dotted lines. We may find it convenient to place in some unoccupied corner of a drawing a layout which could not be in the least justified by any rule of projection. A multitude of transgressions like these occur on good drawings, and they are certainly justifiable from the standpoint of *Utility*, which is the true ultimate end sought for in a practical shop drawing.

These variations from the theoretical are not strictly conventionalities, because they are not classified or established, so far as we know, but are the spontaneous outgrowth, as the occasion demands, of the draftsman's purpose to make his drawing one of greatest *Utility*. He can, however, safely transgress a principle only when he thoroughly knows the principle; otherwise a blind deviation from the theoretical path will inevitably lead to difficulty.

All of the above is intended to impress the student with the idea that theoretical principles are his best, in fact, his only tools to work with; but they are not "self-hardening," like "mushet" steel; they are like the finest grade of tool steel, which must be tempered and ground and used with the best judgment of the operator, to secure the most satisfactory results.

*Student Drawings.* A student's early drawings are usually unsatisfactory, even to himself. Somehow they do not look like those seen in shops, and as a rule he is unable to see why this is so. Of course the difference is to some extent due to the experience of the professional draftsman. However, the superior results of the latter's work are attained largely through his systematic and workmanlike habits of execution. It should encourage the student in his early attempts to know that these essentials to the infusion of life and shop spirit into a drawing can be analyzed, outlined and grasped at the outset by earnest, intelligent effort, and really good workmanlike results obtained. To discuss, and if possible to impart these essentials of a working shop drawing to the student, is the purpose of the present book.

**Essentials.** The two chief essentials of a shop drawing, under which general heads a multitude of detail requirements can be summed up, are:

(1.) Absolutely complete and definite instructions from designer to workman.

(2.) Least possible cost in dollars and cents of production of the drawing measured by the draftsman's time.

It makes no difference how much we may attempt to disguise these two elements, the fact will still be apparent that "*complete instructions furnished for the least money*" is what the manufacturing shop is after, and what will be assumed as a basis for judgment as to highest commercial utility.

*Completeness of Drawings.* As to the first point, that of completeness and definiteness of instruction, there must be no question of degree. If the information which the drawing furnishes is positive and complete, the drawing is good. If doubt arises in the workman's mind as to what the designer intended by a certain line or dimension, or if the dimension be omitted, the drawing is bad. There is no middle ground. The instructions are either present or absent, and the drawing good or bad accordingly.

The workman of to-day is not permitted to assume dimensions or shape. It is his business to execute the draftsman's orders; it is, however, often his privilege to choose his own way of doing it, but further than this modern practice does not allow him to go. He is held as rigidly to the orders specified by the drawing as the locomotive engineer is held to his bit of tissue telegraphic order to proceed, without which he dare not enter the next block. The drawing is supreme; it is official; it must be plain, direct and all-sufficient. It is the draftsman's business to make it thus, and he is not a draftsman until he does.

This idea of positiveness must be thoroughly absorbed by the student. Positive action must be a habit which controls his every move, which marks every dimension he prints, which directs every line he draws. Every line must mean something, must have a definite reason for existence, must be necessary to illustrate the idea which he wishes to convey to the workman, and every line must be a definite measurable distance from every other line, so that its location is fixed beyond a doubt. Lines which mean nothing, and cannot be measured, have no place on the drawing; they only confuse it.

A good picture of a machine could scarcely be called to the same service as a good drawing of it. The picture might give us an excellent idea of the machine, but for the purpose of the actual construction the picture is useless, while the drawing is of positive value. This value exists simply because of, and in proportion to, the completeness of detail which it shows. Hence in making a shop drawing the picture idea is entirely subordinate to the idea of *Utility*, the latter in fact being the measure of its value.

There are certain classes of drawings—of which the Patent Office drawing is a good example—in the making of which the picture idea is predominant. Here the purpose is to illustrate mechanisms, not construct them; hence the function of the drawing is in no wise that of the working shop drawing, and as such does not fall within our discussion.

*Cost of Producing Drawings.* The second general element involved in producing shop drawings is their cost, as measured by the draftsman's time. It is somewhat subordinate to the first element, for the drawing must be a good one, judged by an absolute standard, whatever the time or cost necessary to produce it. Cost, however, is an important item, and cannot well be overlooked. It is inevitable that in any enterprise economy will ultimately be sought, whatever extravagance an imperative original demand may have permitted. This is as true in the production of drawings as in the case of manufactured articles of trade. Drafting-room labor is a relatively high-priced service, and the salary list easily assumes considerable proportions, so that wasteful excesses count up rapidly. One of the qualifications of proficiency invariably required for this department of shop organization is rapidity of execution. This is not as dependent upon personal traits as at first might be supposed. A man may so husband his time and direct his efforts that he will easily distance his neighbor of more rapid motion. The latter may have less ability to make his energies count, and lack of judgment as to when just enough, and no more than enough, energy has been expended on his drawings. From the standpoint of *Utility*, the function of a drawing is fulfilled when it has reached the stage that it *completely* instructs; more time spent in elaboration is wasted, and is an unnecessary and therefore extravagant expenditure. The student must fully realize this. In his earnestness to produce finished and complete work he must constantly strive to accomplish results in the least possible time. This does not mean careless haste; far from it. A complete shop drawing cannot be made by short cuts, but through a systematic building of line on line, dimension on dimension. This is in sharp contrast to a haphazard habit of developing a drawing, first a line here and then a figure there, with no definite purpose in mind, and no hint as to when the drawing is actually completed.

The one method constitutes the efficient draftsman who works easily, receives a high salary, and is worth it, because he wastes no time in unnecessary labor. The other marks his unfortunate brother, plodding laboriously far behind, receiving a small pittance per hour, and worth less, because he does uncalled-for labor, and loses his definiteness of purpose in a maze of unexplainable lines and figures.

*A working shop drawing*, commercially considered, may well be defined as being "*Complete instruction from designer to workman issued at minimum expense.*"

This definition should be memorized by the student, and constantly kept in mind while making a drawing. The preceding pages should be re-read with this in view until the full spirit is appreciated.

The maxim as given above, if faithfully adhered to without modification, answers nearly every question that can be raised as to the excellence of a drawing. It can be used as a standard of judgment, whatever system of lines or symbols may be in vogue. It permits a draftsman to adjust himself to the rules of any shop or drawing-room, and yet produce a good drawing and satisfy his employer.

A drawing which is cheaply produced and at the same time does perfectly that for which it was made, that is, convey complete instruction, is beyond commercial criticism.

**Method of Procedure.** As the general objects to be attained in a working shop drawing have now been presented, it is necessary to indicate in detail how the work may be properly accomplished. In order to do this, it is proposed to produce systematically a full set of working drawings of a familiar and comparatively simple machine. The methods used will be those of a designing detail draftsman, producing commercial work fit for shop use. In the progress of the work, from its beginning in the rough, though accurate, pencil layout, to the completion of the tracings and the order sheets, the same bold style, clearness, directness and businesslike spirit which the shop atmosphere and surroundings would naturally supply, will be emphasized, and so far as possible imparted to the student. It is expected that the student will follow the text closely and study the plates carefully, endeavoring to familiarize himself with every detail illustrated. The more closely he is able to apply himself in this respect the more will he be able to partake of the life and spirit which is intended to be conveyed, and without which the true character of the work can be but poorly developed.

Incidentally, several purposes will be fulfilled by this treatment.

Ability to read drawings quickly and intelligently is almost as important as making them, and it is expected that the study of the plates, with a view to thoroughly understanding every line, will develop proficiency in the art of reading drawings.

The discussion in the text, of not only the form of the machine parts themselves, but also the tools and shop processes to produce them, affords considerable insight into the influences affecting good machine design. Without introducing any mathematical analysis or investigation, which is beyond the province of this book, much practical consideration as to the restrictions imposed by existing shop methods upon theoretical construction will be suggested, and the student encouraged to use his judgment thereon.

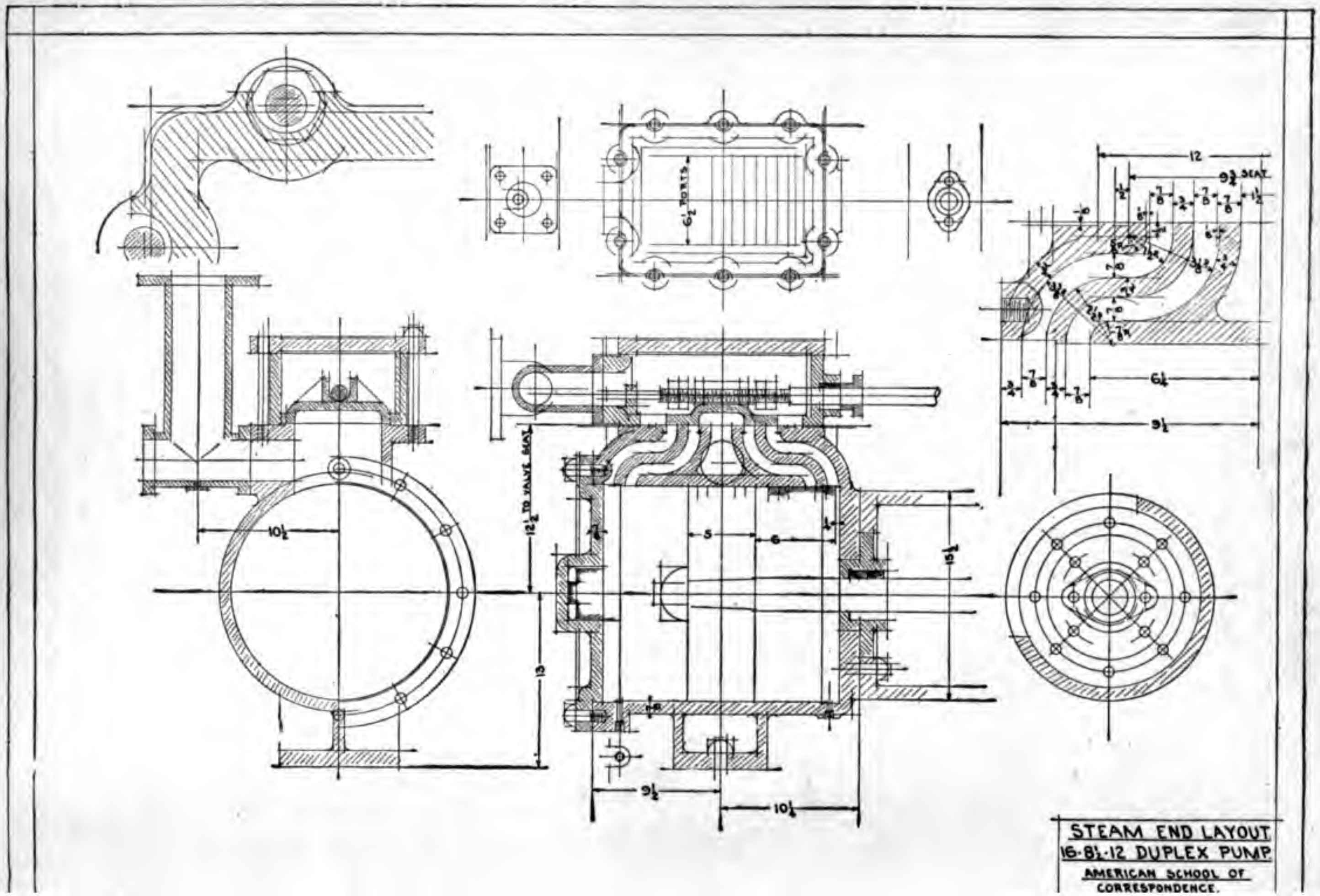
In the preliminary layouts the actual "sketchy" appearance of the pencil drawing will be imitated as far as possible, so that the student himself may imitate and catch the bold dash, yet fine accuracy, of the line-work, which is characteristic of the expert draftsman.

The completeness of a *set* of drawings is as important a lesson as the completeness of each drawing itself. In this is involved the proper arrangement and classification of details, the foundation layout, and the system of order sheets for getting work into and through the shops. This is a feature which very strongly affects some of the finishing touches to a drawing, for it is so easy to omit a "few last things" and turn in an uncompleted sheet. Every draftsman knows how many little things come up toward the close of a job involving complete drawings of a machine, and how strong the tendency is to omit them, and relieve himself of somewhat tedious details. The result is irritation and delay when the drawings get into the shop, and they return to the drawing room to be fixed up at a time probably inconvenient for all parties concerned. A good draftsman will turn in a *complete* set of *complete* drawings. It is highly important that the student grasp this idea, and study his work accordingly.

## DUPLEX PUMP PLATES.

The typical set of plates chosen for this book in fulfillment of the above purposes, takes up the study of a simple, duplex steam pump. This particular type of machine represents the simplest and most elementary form of the steam engine in modern use in respect to valve gear and controlling devices. It is not an economical machine, yet its principles lie at the foundation of the economical high-speed engine, the latter being produced through a modification of the uneconomical valve gear such as is found on a pump of the type chosen, rather than through any radical change of construction as to the body of the machine. Hence the study of a steam pump may well precede that of higher forms of the steam engine. It is hoped that the study will so interest the student that he will be led to further investigation and development not only of the steam engine itself, but of that highly important division of modern engineering,— pumping machinery.

Thus we note another point of advantage in the study as out-


STEAM END LAYOUT
16·8½·12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE.
6½ PORTS
12½ TO VALVE SEAT
9¾ SEAT
12
6¼
9½
15¼
13
10½
10¼
5
6

lined. The power end of the machine introduces us to the steam engine; the load end is the beginning of the engineering of pumping machinery.

*Rating of Pump.* A steam pump is rated by the bore of its cylinders and length of stroke, all being given in inches. A "$16 \times 8\frac{1}{2} \times 12$ pump" means that the steam cylinder is 16 inches in diameter, the water plunger $8\frac{1}{2}$ inches in diameter, and the nominal length of stroke 12 inches. These sizes are always given in the same order, beginning with the diameter of the smallest cylinder (in case there is more than one), then the diameter of water plunger, the common stroke of both being placed last. This expresses to the mechanic the rating of the pump in the clearest style and briefest language.

The pump illustrated here is designed for standard service, operating under a steam pressure not to exceed 100 pounds per square inch, water pressure not to exceed 150 pounds per square inch, and the rated capacity based on an average piston speed of 100 feet per minute being about 550 gallons. This requires that each side of the pump shall handle 275 gallons, and being double acting, shall make 100 reversals or 50 double strokes per minute.

**Plate A. Steam End Layout.** This plate illustrates, as nearly as reproduction can accomplish, the pencil layout of the steam end. It is the first work of the designing draftsman. The drawing as shown is exactly the type of layout which he would turn over to a detail draftsman, whose duty it would be to work up detail shop drawings therefrom.

The character of this drawing should be carefully studied. Remember that it is a layout, nothing more; also bear in mind that it is an exact, measurable working sketch. Attention is called to the sharpness of the lines, especially to the clean-cut intersections. Note the boldness, dash and businesslike style, the freehand cross-section lines roughly put in. There is no hesitation or worry as to where the end of a line shall be, or whether it crosses other lines which it theoretically should not. The intersections are allowed to indicate the termination of lines, and the rough section lines pick out the parts and separate them clearly to the eye. There is the spirit in this layout of confident, definite and rapid action, with no thought for absolute finish in line-work, but with every thought for absolute results as to measurable dimensions.

The data for the production of Plate A by the student are rather more complete than he would usually find in practice. Plates E, F and G show many details fully.

The steam cylinder and head, however, as shown in Plate G, are not dimensioned, and the student's problem is to produce this plate complete, with finish marks, dimensions and necessary data for a working drawing. In order to do this it is first necessary to work up Plate A with exactness, in pencil, and see that all parts go together properly. Then the detail of cylinder and head may be made separately by measurement of the layout drawing, and Plate G produced.

For this work the ordinary brown detail paper is very satisfactory. A hard lead pencil is necessary, as hard as 6H, and the point must be kept well sharpened.

There are two general rules of action in producing a drawing which give the answer to the question which oftenest confronts the beginner: "What is to be done first?" or "What is to be done next?" These rules are:

1. Draw everything that is positively known.
2. Work from the inside to the outside.

Every problem has some positive data, assumed or calculated, to start with. The first thing to do in every case is to get this data represented by lines on the paper. An expert designer has been heard to say that until he had spoiled the blankness of his sheet of paper by some lines, he could not design. There is something in this; and almost invariably the first line to draw is a horizontal center line somewhere near the middle of the sheet; draw it! Draw it at once without hesitation, and the layout is begun. We now have something about which to build.

In this case the designer would first calculate the size of the piston rod, and determine the fastening to the piston. He would then draw the rod and build a hub around it. He would next calculate the width or thickness of piston and size of packing rings, and draw the two vertical lines 5 inches apart, to indicate the piston faces. These lines would be limited by the cylinder bore, which he knows to be 16 inches; hence horizontal lines 16 inches apart, parallel to and symmetrical with the center line, are the next to be drawn. Short vertical lines indicate the location of the packing rings. As the nominal travel of the piston is to be 12 inches, the location of the piston and rings can be shown on both sides of the central vertical line at the limits of travel. A clearance must exist between the heads and the piston (in this case $\frac{1}{4}$ inch is allowed), hence the lines of the heads can be drawn, and the general inside outline of the cylinder barrel is complete.

This is all in direct application of the foregoing rules, and is so simple, natural and direct that it hardly requires such explicit statement. We have simply taken such data as we had and put it on paper, placing it where it can be seen from all sides, and where the mind is relieved of the labor of carrying it.

If the student will only appreciate this one rule and draw all he knows about the problem, he is well on his way to its solution. *Draw everything you know, and work for what you don't know*, is what these two rules say, and the first question to arise should be: "Have I drawn everything that is known about the problem?" before he asks himself or any one else: "What shall I do next?"

One other rule might be added to these two: *Keep dimensions in even figures, if possible.* This means that small fractions should be avoided. It is just as easy to bear this point in mind, and save the workman much annoyance and chance of error, as it is to disregard this matter. Even figures constitute one of the trade-marks of an expert draftsman. Of course a few small fractions, and sometimes decimals, will be necessary. Remember, however, that fractions must in every case be according to the common scale; that is, in sixteenths, thirty-seconds, sixty-fourths, etc.; never in thirds, fifths, sevenths, or such as do not occur on the common machinist's scale.

A systematic, definite mode of treatment on these lines must become a habit, so that all problems, however complicated, can be approached with confidence in the same way. It is the drawing of one line which makes clear the drawing of the next and subsequent lines; and the most serious obstacle which the student is likely to set for himself is trying to see the whele problem through from the beginning. Even an expert cannot do this, but allows the layout to develop results as he proceeds.

The details of the piston and rod being given in Plate E, the foregoing work is very easy for the student. The thickness of the barrel and heads being determined ($\frac{7}{8}$ inch in this case), the exterior outline may be partially drawn. The fixed head at the yoke end must be thicker than this, in order to receive the yoke and stuffing-box bolts without breaking through. The recesses or counterbores at either end of the cylinder should be so located that the packing rings run over the edge a little at the end of the stroke, thus preventing the wearing of a shoulder by the piston stopping in the same place every time. The counterbore should be deep enough to allow reboring the cylinder without the counterbore being touched by the tool. In this way the counterbore is retained to center the cylinder at its original location.

The size of steam ports having been calculated, they may be drawn in, the turns being made easy and as direct as possible. The height to valve seat must be kept at the lowest limit consistent with sufficient metal between and outside of the ports. As the detail of the ports might be somewhat troublesome, it is shown in an enlarged sketch for the student's benefit. Chipping or filing strips $\frac{1}{8}$ inch high are left on the port edges, which must be true, in order to finish them up easily.

The three inner ports are for exhaust, the outer ones for admission of steam. This five-ported cylinder is peculiar to the direct acting steam pump, it being a device to effect the cushioning of the piston at the end of the stroke, thus preventing the piston from striking the heads. This is necessary, since no positive limit of motion exists, as is the case in machines with crank and connecting rod.

When the edge of the piston has passed the outer edge of the exhaust port, as shown in Fig. 1, the steam, which has been exhausting through port A, is confined in space B and port C, and, being compressed by the piston, acts like a spring to retard its motion. If the point P is properly determined for a given speed, the piston will always compress the steam just enough to cause it to stop at the end of the nominal stroke; in this case, $\frac{1}{4}$ inch from the head. It is evident, however, that at different speeds the piston will have more or less power to compress the steam, and will not stop at the point desired. This causes the trouble of "short stroke," and consequent inability to make the pump work to its full capacity. Now if we connect ports A and C by a small opening shown dotted at D, and control this opening by a plug valve operated by hand from the outside, we can let a little steam leak by into port A, thus reducing the cushion and allowing full stroke.

In order to avoid complicating the drawing, no cushion valves are shown or required to be put on by the student. They are not customary in small pumps, but might advantageously be put on the present illustration.

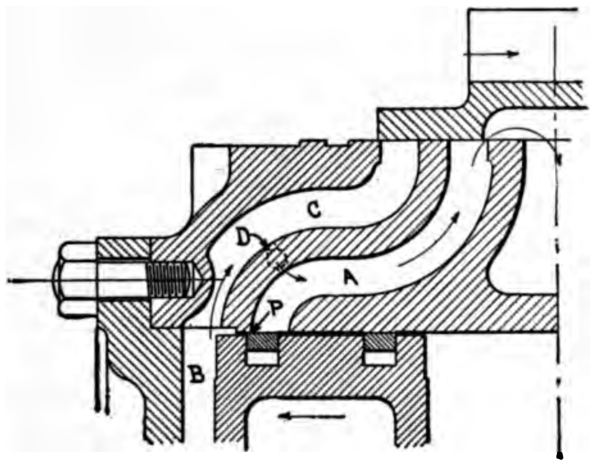



Fig. 1.

The valve seat must be a scraped surface, while the chest face need not be; hence the latter is finished $\frac{1}{8}$ inch lower. This also gives a ledge against which the steam chest fits, thus securing positive location.

The bolting of the heads and the steam chest should allow a width of packing inside of the bolts of $\frac{1}{2}$ to $\frac{5}{8}$ inch, otherwise there is danger of the steam blowing out the packing and causing leakage around the bolts. The bolts do not fill the holes, the latter being drilled large, from $\frac{1}{16}$ to $\frac{1}{8}$ inch. The spacing, if wider than 5 or 6 inches, is likely to permit springing of the flanges between the bolts, and consequent leakage. Bolts less than $\frac{5}{8}$ inch diameter are not desirable, as they can be easily twisted off with an ordinary wrench. In this case the cylinder head takes $\frac{7}{8}$-inch bolts, the yoke, stuffing-box and gland, $\frac{3}{4}$-inch.

The flanges of heads and cylinders are usually from 25 per cent to 50 per cent thicker than the body of the casting.

Drips, $\frac{3}{8}$-inch pipe tap, to be fitted with cocks, are necessary at both ends of the cylinder to readily drain the cylinder of water.

*Molding of Steam Cylinder.* The design is often influenced by the way in which the piece is to be cast. It often takes but a slight change of design to save many dollars in pattern making and foundry work. Hence the habit should be formed of always judging the design of a piece from the foundry standpoint. In this case it is evident that the ports and cylinder bore must be cored out, and the most obvious position of molding is to lay the cylinder on its side, the parting line of the flask being along a vertical plane running lengthwise through the middle of the cylinder. This permits the chest flanges to draw nicely, likewise the ribs on the foot, and allows the thin curving port cores to stand edgewise in the mold.

Another method of molding would be with the valve seat down. This would involve loose pieces for the chest flanges, and setting of cores for the cylinder foot. It would, however, assure sound metal beyond question at the valve seat. Spongy metal at the important wearing surfaces, the valve seat and cylinder bore, is not permissible in any case, and care in molding, and good design, is necessary for good results.

All corners must be carefully filleted, and chunks of metal must be avoided, especially where several walls or ribs join. The metal must be kept of average uniform thickness, so that the whole casting will cool uniformly.

*Machining of Steam Cylinder.* The boring may be done on a vertical boring mill, the heavy arm carrying the tool being thrust down unsupported into the cylinder, the latter being rotated by the table to which it is clamped. If the horizontal boring machine be used, the hole through the inside head for the stuffing box must be large enough to permit a stiff boring bar to be passed through. This allows a support at each end of the bar, to take the strain of the cut.

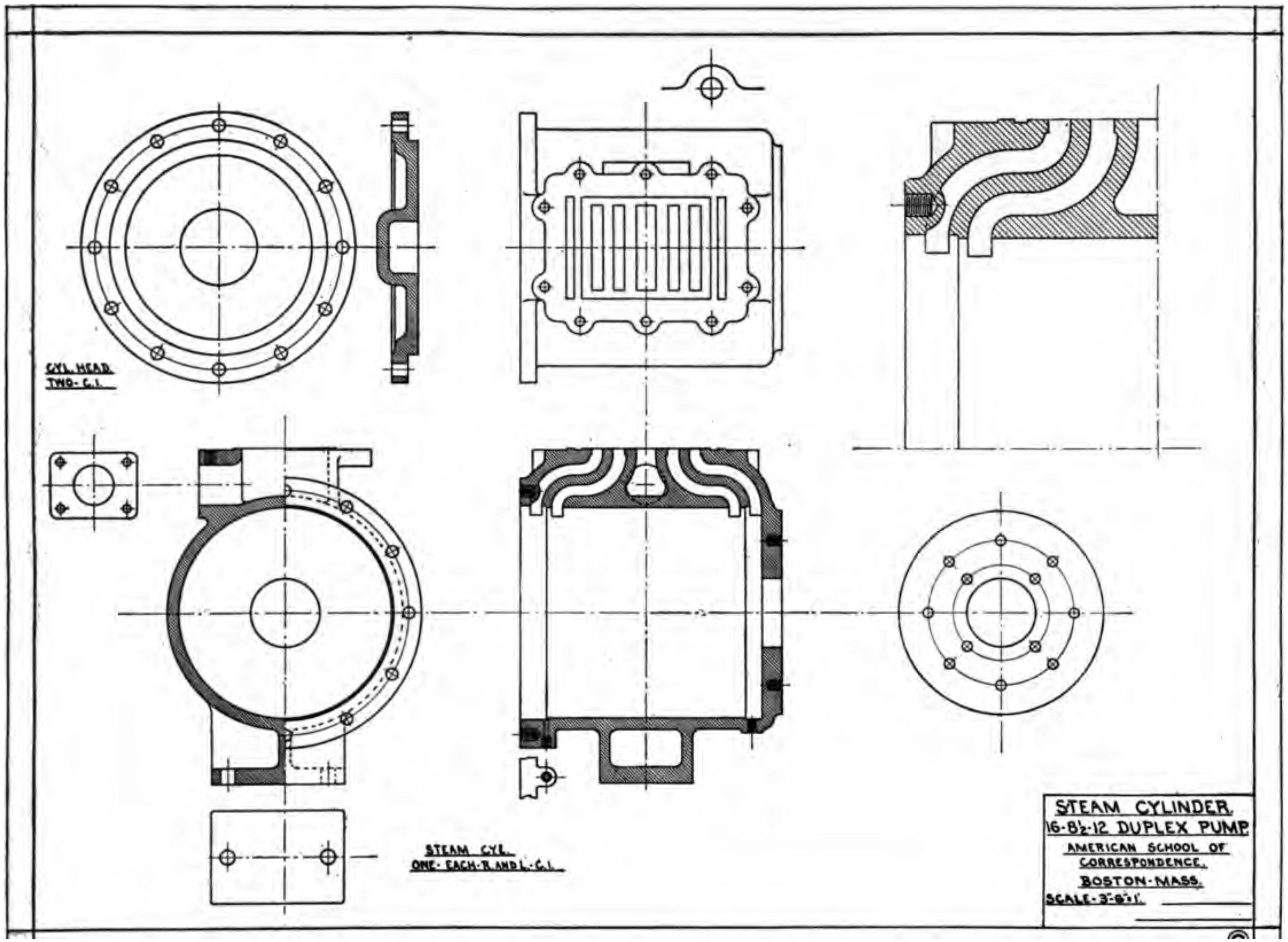
The plane surfaces may be finished on a reciprocating planer or a rotary planer. In the latter case it is desirable to keep all lugs or projections back from finished surfaces, to permit the large round head which carries the cutters to pass over them without interference.

The drilling of standard machine parts of this character is usually done through jigs, or plates carrying hardened steel bushings laid out to correspond with the holes required, and through which the drill is guided. These plates are located by some fixed line or lug on the casting, and then clamped fast, thus assuring exact duplication and rapid drilling, and avoiding the tedious laying out of the holes. In order to save changing the drill it is desirable, if possible, to maintain the same size of hole on any given surface. Of course it is not always admissible to do this.

**Plate G. Steam Cylinder.** After the exact and complete development of the steam-end layout, the student should be pretty thoroughly acquainted with the details of the cylinder. All the work thus far has been entirely for *his own* information, to get his ideas in visible shape, so that he himself can have a permanent record of them. This layout, however, is not in suitable form to finish up into a detail drawing. Its sketchy nature and the confusion of parts, especially if attempt were made to add dimensions, would render it somewhat difficult to be read by a workman taking it up as an unfamiliar subject. Hence it is now necessary to separately detail the parts, with the object in view of transferring, in the simplest and most direct manner, specific information to the workman which will enable him to construct the several parts. It is not enough now that the drawing be clear to the man who makes it; it must be clear, *absolutely clear*, to the shop mechanic, who has no means of knowing the designer's plans except through the information which the drawing gives on its face.

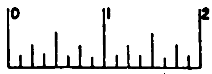
This requires that the draftsman should put himself in the workman's place, and forestall, by the explicit nature of his drawing, all possible questions which may arise in the shop. In this way only can he hope to avoid errors of construction and the continual annoyance of endless explanation of his orders.

Plate G is to be a finished drawing, and the first thing to do is to lay out the sheet. The standard sheet for details which has

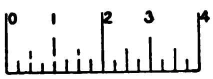

CYL. HEAD
TWO-C.I.
STEAM CYL.
ONE-EACH-R. AND L.-C.I.
STEAM CYLINDER.
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF
CORRESPONDENCE.
BOSTON-MASS.
SCALE-3"=1'.

been adopted is 18 × 24 inches trimming size, with $\frac{1}{2}$ inch margin all round, so that the working space is 17 × 23 inches. The rectangle for the title is to be laid off $2\frac{1}{2} \times 4$ inches in the lower right-hand corner, and must never be altered, either in size or position. This does not mean that other sizes are wrong, but once a standard system is adopted it must be strictly adhered to, both for artistic and commercial reasons. The scale to which the drawing is to be made is indicated in the title corner on every plate.

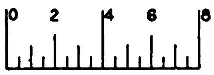
The scales permissible for shop drawings in the United States are those readily derived from the common foot rule, such as full size, 6 inches = 1 foot, 3 inches = 1 foot, $1\frac{1}{2}$ inches = 1 foot. These are the most common, most easily read from an ordinary scale, and one of these can usually be adopted. The student should learn to read these from an ordinary scale without being confined to a special graduation. To do this it is not necessary to divide each dimension by 2, 4 and 8 to get half size, quarter size, or eighth size, and then lay down the result. For half size, or 6 inches = 1 foot, $\frac{1}{2}$ inch on an ordinary rule represents 1 inch. Hence, each half inch may be read as 1 inch, and its subdivisions accordingly, thus:




For 3 inches = 1 foot, or quarter size, $\frac{1}{4}$ inch represents 1 inch, and looks thus:




For $1\frac{1}{2}$ inches = 1 foot, or eighth size, $\frac{1}{8}$ inch represents 1 foot, and looks thus :




It is very easy to get accustomed to this, and it saves much time and trouble hunting up a special scale every time.

The other allowable scales, less common, but sometimes necessary on large work, are 1 inch = 1 foot, $\frac{3}{4}$ inch = 1 foot, $\frac{1}{2}$ inch = 1 foot, $\frac{3}{8}$ inch = 1 foot, $\frac{1}{4}$ inch = 1 foot, and $\frac{1}{8}$ inch = 1 foot. To use these scales conveniently, special graduation is desirable.

The general arrangement of the sheet, number of views and approximate space occupied, should be blocked out first. This can easily be done from the original layout. In general, several cross-sections are preferable to a single view, which involves many dotted lines. Dotted lines are very convenient for showing invisible parts of an object, but they are often abused, and the drawing of a complicated piece made indefinite and confused thereby. As already stated, a working shop drawing is solely to convey information to the workman at the least possible cost. A careful consideration of this will settle the question of the number of views necessary, their character, and the amount of dotted line work desirable.

Never let the drawing become the master; always be master of the drawing. Do not draw an extra view if no use can be seen for it. Do not put in dotted lines if the detail is completely shown without them. Full lines, or lines which show visible portions must, of course, be shown completely.

The nature of the pencil work on Plate G should be the same as on the original layout; viz., sharp, definite lines and positive intersections. Above all things learn the habit of accurate workmanship, for it will save many errors and a vast amount of time. The draftsman must check himself at every line he draws. Slight errors in scaling will often throw parts out of proper relation to each other, and interferences, which the drawing does not show, will become apparent only when the parts get into the machinist's hands.

It is dangerous practice to project across from one view to the other. It only takes a slight irregularity or spring in the T-square to vary the location of lines very perceptibly from where they should be, and once out of scale from this reason it is almost impossible to work a view with any certainty. Rather than project across from view to view, the principal lines, at least, should be scaled off on each view, and it will be found that in the end time will be saved and greater accuracy secured.

It is not economical of time to finish one view before beginning another. It is better to take some single detail of the drawing and develop it in all views, in order to study it from all sides. What is completed in one view may be found to be totally wrong when developed from another side, and the time spent on the first view will be wholly wasted. For example, in the present case the steam ports should be drawn in side elevation, end elevation and plan, and when thus completed the mind can leave them and in a similar fashion take up the study of the flanges, then the cylinder foot, and so on. Thus again the draftsman is master of his drawing, for he is continually making it tell him whether he is right or wrong. If, on the contrary, he allows himself to look at but one side at a time, and works from that standpoint alone, it may lead him into many difficulties from which he cannot readily extricate himself.

Do not be afraid to use the eraser. The draftsman who hesitates to draw until he is positive that no change will be necessary, is likely to spend the greater portion of his time in unprofitable dreams, for he is attempting the impossible. A drawing is a means, not an end; and, as has been already pointed out, it greatly assists the draftsman in clearing up many doubtful questions which the imagination alone cannot do.

A bold attack of a problem shows the quickest path to its solution, even if lines must be erased again and again. It is a sign of serious lack of ability to hesitate in the use of pencil and eraser.

Attention is called to the simple, straightforward character of Plate G. Notice the almost entire absence of dotted lines; the enlarged section through the ports, giving ample opportunity for dimensions without confusion; the use of a half end elevation and a half cross-section,—the one to make clear the flange and bolt layout; the other to show the exhaust opening, the small auxiliary views (drawn at convenient points) of the exhaust flange layout, the cylinder foot and the drip boss.

A steam cylinder is a fairly complicated casting; and it would be an easy matter, by the use of elaborate views, the dotting in of parts already completely shown, and careless line work, to rob this drawing almost entirely of its clearness and directness of illustration. *Just what is necessary* (for clearness' sake) *and no more* (for cheapness' sake), is the whole matter in a nutshell, and is what determines its shop and commercial value.

**Dimensions and Letters.** A good line drawing can be spoiled by poorly arranged dimensions and hasty lettering. The five principal points to be kept in mind to develop excellence in this respect are:

(1) System.
(2) Accuracy.
(3) Clearness.
(4) Completeness.
(5) Character.

*System.* The habit of system in placing figures and letters on a drawing is the one element which, to a large extent, controls all the others. If the systematic habit is established early, the other requirements will be fulfilled more easily. A haphazard method will, on the contrary, just as surely prevent the successful cultivation of the ability to figure a drawing. In fact, if the haphazard habit is continued it will itself, by the dissatisfaction which it causes, soon compel the draftsman to change his occupation.

In the first place, whatever part of a machine detail is to be dimensioned, that particular part should receive attention until it has been completely figured. Do not jump from one point to another, putting in a figure here and another there. Stick to one thing until it is done.

For example, take Plate F and the simple detail of the steam pipe. Suppose we start with one of the square flanges. The first question is: "Where is this flange located?" This is answered by the dimensions 5 inches and 12-inch centers, which refer the face of the flange to the center of the pipe and the flanges to each other. The next question is: "What are the three dimensions of the flange,— length, breadth and thickness?" This is readily answered as shown on the drawing. The next question is: "What further description is necessary to completely specify the shape of the flange?" This is answered by the radius of the corners, $\frac{3}{4}$ inch R. Next, "What drilling or special feature exists in the flange?" This is answered by $\frac{11}{16}$-inch drill, $3\frac{1}{2}$-inch centers, and the letter *f* to denote that the face is to be finished.

The round flange of this pipe is approached and figured in the same way, except that the location of the face is preferably referred to the face of the square flange by the figure $8\frac{1}{4}$ inches, instead of to the center of the pipe, because the planer hand will more naturally use this figure.

These flanges are now to be connected by a pipe involving two sizes. The main pipe is 3 inches diameter inside, 4 inches outside, and $\frac{1}{2}$ inch thick, running into the two branches by fillets and radii, as figured. The two branches are really one pipe, $2\frac{1}{2}$ inches inside, $3\frac{1}{2}$ inches outside, $\frac{1}{2}$ inch thick, and sweeping down into the square flanges by 4-inch radius.

This systematic method takes longer to explain than to actually execute, but it is typical of the train of thought which must be followed on all pieces, simple or complicated, in order to properly place dimensions.

In general, it may be stated that all parts of a piece must be referred either to each other, or to some common reference line, or to both. Each part so referred must then be figured as a piece by itself, and then its connections to the principal structure. Thus, figuring a machine detail involves three things:

(1) Relative location of its parts.
(2) Proportions of these parts.
(3) Proportions of connecting members.

As in the original design of a piece so in the figuring of it, the draftsman must as far as possible put himself in the place of the workman, judging the methods and processes of construction and available tools. This will largely influence the arrangement of the dimensions. Of course it implies considerable experience in shop work, which some students do not possess. He can begin none too early, however, to learn to look at his work from the shop standpoint, and surely make it some better on that account.

Pieces must not only be systematically dimensioned, but regularly specified and called for by suitable titles.

A title should specify at least three things:

(1) Name of piece.
(2) Number wanted for one machine.
(3) Material.

To these might be added a fourth; viz., pattern or piece number. The latter is not specified on the drawings under discussion, because systems of pattern and piece numbering are so varied that little would be gained by developing one for this special study.

These titles should always be put on in the same way, as the workmen become used to a certain system and are likely to misunderstand directions if a regular plan is not followed. A good way to arrange titles is suggested on the plates, although there are others which might be used.

Bolts are usually specified by diameter and length under the head, the length of thread being to some standard system in use by the shop, unless otherwise called for. Bolts are specified on the sheet containing the piece into which they are tapped. In the case of through bolts, tapped into neither piece, they are preferably called for in connection with the principal member.

*Accuracy.* Of course the dimensions on a drawing must be accurate. It is, however, a very easy matter to make errors. To insure accuracy a figure must *never* be put down carelessly, and a constant watch must be kept that scaled figures add up to over-all dimensions. It will not do to rely on scaling alone, as a very slight variation from exact scale may throw two dimensions out with each other. In spite of all the care that can be exercised errors will creep in, and a final thorough checking must be given a drawing before it is pronounced complete. A good rule to follow in checking up is to "assume everything wrong until it is proved to be right."

*Clearness.* As in the line drawing itself, there must be absolute clearness of instruction by the dimensions. Any doubt as to what a figure is, or what it means, rules out that figure as part of the drawing. If a piece is made wrong because doubt of this character is transmitted to the workman, the draftsman is always held responsible for the error.

Figures should, in all cases, be placed where they can be most clearly read. They should be bunched on a single view as far as possible, but not when greater clearness demands that another view be used. It hinders the reading of a drawing materially if the eye is forced to jump over large spaces of the sheet from view to view, to catch the several dimensions of a small detail. Usually it is easy to so group figures as to avoid this.

It is a good plan to keep dimensions off the body of the drawing, when it can be done so conveniently. It is not worth while, however, to go out of one's way to do this, as figures in the open spaces of a detail do not at all destroy its clearness.

Extended notes on a drawing to make it clear should not be required, but they should be used without hesitation if any doubt exists. An explicit note of instruction is the final resource for clearness when the art of drawing fails of its purpose, as it sometimes does.

*Completeness.* A detail is completely dimensioned when it shows *all* the figures necessary for the workman. Anything short of this is incompleteness. As modern shops hold the draftsman solely responsible for the design, the mechanic is not allowed to modify it by filling in any omitted dimensions. The only way to be sure that all the dimensions are on is to systematically go all round a piece inside and out, according to the method suggested under the paragraph on "System."

It is a good plan to always bear in mind that not only the machinist is to use the drawing, but also the pattern maker. For the benefit of the latter, special attention is desirable in figuring the cores. This saves him some addition and subtraction. In general, it has been found that less chance of error exists if mathematical work is not required of the shopman, all necessary data being furnished on the face of the drawing.

*Character.* By character in figures and letters is meant uniform style, height and slope, and a certain boldness peculiar to the work of the expert draftsman. The last is difficult for the novice to acquire. The student should not be discouraged because his efforts do not look like impressions from printers' type. Artistic excellence is the result of long experience, but is based on character. If the student can once get character into his work, the artistic feature will, with careful and constant practice, gradually develop. It is safe to say that there is no one element of a drawing which more positively stamps it as the work of an amateur than the character of the lettering, and every attention should be paid to getting out of the apprenticeship stage in this respect. Freehand lettering only is permitted in the drawings illustrated herewith. Ruled letters are seldom found on any working drawings, as the element of time involved is so great that few shops are willing to pay for it.

Uniform style requires that if capitals only are used in titles, they only must be used in notes and elsewhere on the drawing. If lower-case letters are used, they must be used in every part of the drawing. One style should not be mixed with another. The height of the letters should be limited by two horizontal lines, and though practice may render the upper line unnecessary, it takes but an instant to draw it, and uniform height is then assured. A good height for titles of details such as are illustrated is $\frac{5}{32}$ inch. The height once chosen should be adhered to throughout the whole set. A medium, not a hard, grade of pencil (3H) will give the hand greater freedom. A great temptation exists to omit titles from the pencil drawing, simply inking them on the tracing. This is false economy of time, for in the end it will be found that enough time will be saved by the certainty with which the tracing can be made to more than pay for the labor on the pencil drawing. Again, it permits the tracing, in regular shop practice, to be made by cheaper labor than that which produced the pencil drawing.

Uniform slope is most easily acquired by the use of guide lines put in at frequent intervals. A small wooden triangle can be made, giving the required angle. The angle of the letters shown on the plates is 9 degrees, or about 1 inch slope in 6 inches. The question as to whether letters should incline backwards, forwards, or stand vertical, does not enter this discussion. Character is not affected by the slope. The student may choose whatever comes most natural to him, but having chosen, the character of his work will be spoiled if he varies it. The most difficult of the three is the vertical style; hence most draftsmen incline their letters. The backward slope is used on the plates of this shop drawing paper, thus giving the student opportunity to compare with plates in the earlier books, and follow his preference.

The effect of change of style, height and slope is shown in Figs. 2, 3 and 4, respectively. Attention is called to Fig. 5, which is a sample title, in which these points are corrected.

*Principal Titles.* The principal title of a drawing should contain at least seven items:

(1) Name of principal details shown.
(2) Name of machine.
(3) Firm name and location.
(4) Scale of drawing.
(5) Date of completion.
(6) Draftsman's signature.
(7) Filing number.

To these are often added others, but for purposes of filing and reference the above at least *must* be put on. The filing number may or may not be put in the title frame, but it is really a part of it. It is often put in the margin below the title.

An arrangement of title should be established and then followed exactly, without variation either as to location on sheet or detail make-up. Abbreviated words are always permissible in titles, provided the meaning is clear. Special care must be taken in punctuation, however, as a title, whether abbreviated or not, has an unfinished appearance if the periods, commas and other necessary punctuation marks are not included.

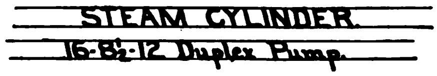



Fig. 2.

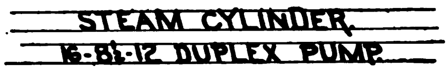



Fig. 3.

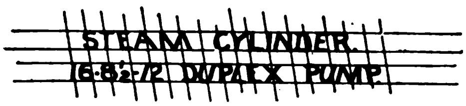



Fig. 4.

The sample title illustrated in Fig. 5 indicates the arrangement chosen for the drawings of Part IV. Note that it is necessary in this special case to add an extra subject to the seven given above; viz., the residence of the student draftsman.

This style of title must be put with care on every drawing, even on the rough pencil layouts. In the latter case it may of course be left in pencil, as the rough layouts are not to be inked.

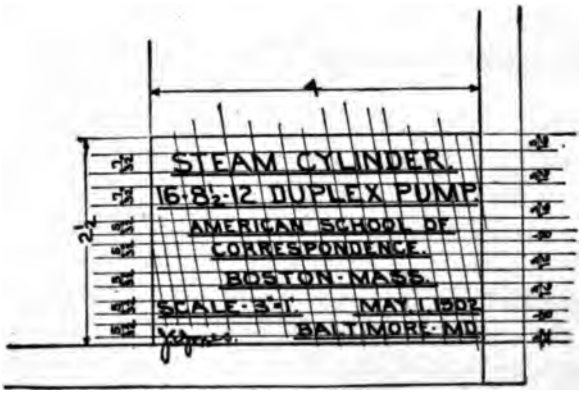



Fig. 5.

**Inking and Tracing.** Both bond paper and tracing cloth are used in business practice for finished drawings. It is desirable to keep a stock of both in any drawing office, so that either may be used as occasion requires. Bond paper stretched on the board gives a beautiful surface to take the ink, and very handsome and effective detail or assembled drawings can thus be produced.

Changes are not quite as readily made on bond paper as on tracing cloth, and it takes a little longer to make the blue print. In other ways the bond paper is not quite as flexible to use as the tracing cloth. However, one must be guided entirely by shop conditions to settle the question of preference. As the tracing cloth is generally used, and suits the purpose of the student better, it will be required in this work.

The inking should be done on the *rough* side of the cloth. One reason for choosing this side is that as the cloth tends to curl under toward the glazed side, the drawing as it lies right side up will tend to straighten itself. This seems to be a small point, but it is a very important advantage for filing and for the convenience of those who are to handle the drawings. Also the rough side takes colors and inks better than the glazed side. To trace on the glazed side is not wrong, for it is often done, but it possesses no advantages of its own, and has the disadvantage mentioned above.

Chalk dust scattered over the surface of the cloth after it is tacked down will remove the slightly greasy coating which prevents the ink from flowing well from the pen. This is always necessary if the glazed side be used, and usually for the rough side. The chalk must be carefully removed from the cloth before inking.

The first step in inking is to draw the center lines. Remember that *accurate intersections* are of the utmost importance. No circle is complete without two intersecting lines, preferably at 90 degrees, to determine its center, and these lines should be inked before the circle. When this is done a definite point exists for the needle point of the compasses. If the circle is drawn first the needle point may not be placed accurately at the center on the pencil drawing beneath, and the location be thrown out.

Likewise the principal center lines of pieces, the lines around which the pencil drawing was built up, should be at once put in.

The main body of the drawing, the full lines, should be taken next. In general, circles and arcs should be inked first, but there are cases where it is easier to run the arcs into the straight lines than to match the straight lines to the arcs. They are exceptions, however, and can be judged only as the case arises.

Straight lines, horizontal and vertical, should be inked with the T-square and triangle *in position*. It is a common practice to dispense with the use of the T-square entirely in inking in, using the triangle to match the lines to the arcs already drawn. A necessity for this implies very poor work on the arcs, for with any reasonable care true horizontal and vertical lines will match the arcs all right. With regard to time required, the accuracy with which the T-square may be brought up to a line, or the triangle set on the T-square, more than makes up for the time gained in even an approximate setting of the triangle without a guide. It is just as easy to cultivate the habit of holding the T-square and triangle with the left hand and the pen with the right, and draw an exact line, as to lapse into the other method, which is not workmanlike.

The lines of the body of the drawing depend for their width upon the size of the detail. For a large piece they may be $\frac{1}{32}$ inch wide, and the shade lines $\frac{3}{64}$ inch. For a small detail such widths would be too great. Remember that *contrast* is the principal aim, and to produce it is the only reason why we use different kinds of lines on a drawing. Hence the greatest care must be exercised to prevent body lines from becoming confused with center or dimension lines, and *vice versa*. Also thick lines are desirable for the production of a bold blue-print.

Shade lines are shown on Plates I, K and N only. They are put on according to principles already explained. They certainly improve the drawing from an artistic standpoint, and the student should know how to put them on when desired. Whether or not it is desirable to adopt them on all working drawings is not the purpose of this book to decide, or even discuss. Almost always drawings can be made perfectly clear without them, and are so made and satisfactorily used in probably the majority of shops. Some shops are willing to pay for the extra time necessary to put on shade lines; this, however, is purely their own investment.

Cross-section lines are usually drawn at an angle of 45 degrees with the horizontal, and on sections which are adjacent to each other the slope should be in different directions. If three or more sections come together the width between section lines can be so changed as to indicate clearly the different parts. An example of this is shown in Fig. 6.

The spacing of section lines must not be too fine, rarely closer than $\frac{1}{16}$ inch, more often from $\frac{3}{32}$ to $\frac{1}{8}$ inch, else the labor involved is too great and uniformity practically impossible. It is a waste of time to rule in section lines on the pencil drawing; they may be sketched in freehand, as shown on the original layout of the steam cylinder. Even spacing concerns the tracing alone, and the student should train his eye to regularity as he traces. The thickness of section lines may be intermediate between that of center lines and body lines of the drawing.

*Inking Dimensions and Letters.* Extension lines may be dotted, as explained in Part III, or they may be fine, full lines, the latter method being illustrated in the series of pump plates in this paper. Dimension lines are also often made fine, full lines. If these lines are made full they should be made as fine as it is possible to draw them and still have them firm, clear lines. The same width should be used as for center lines.

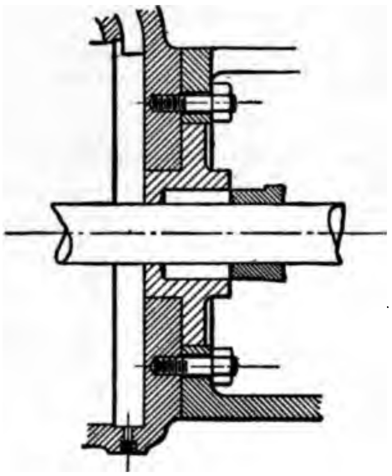


Fig. 6.

Character in inked figures and letters is more difficult to attain than in pencil work. In the first place a pen suitable to the style of drawing is necessary. A civil engineer's fine mapping pen, which gives character to his drawing, is not desirable in producing the bold character of a machine drawing. For the latter choose a rather stiff, blunt pen which is not "scratchy," but runs smoothly, making a line of uniform width. A pen with a round, or ball-shaped nib, recently put on the market, answers the purpose well for ordinary details. A bold, free stroke should be made with the idea of producing a smooth, even line, finished at the first trial. The hesitating uncertainty of the beginner's hand produces a "shaky" letter, and going over a letter or figure twice or more to smooth it up usually makes it worse.

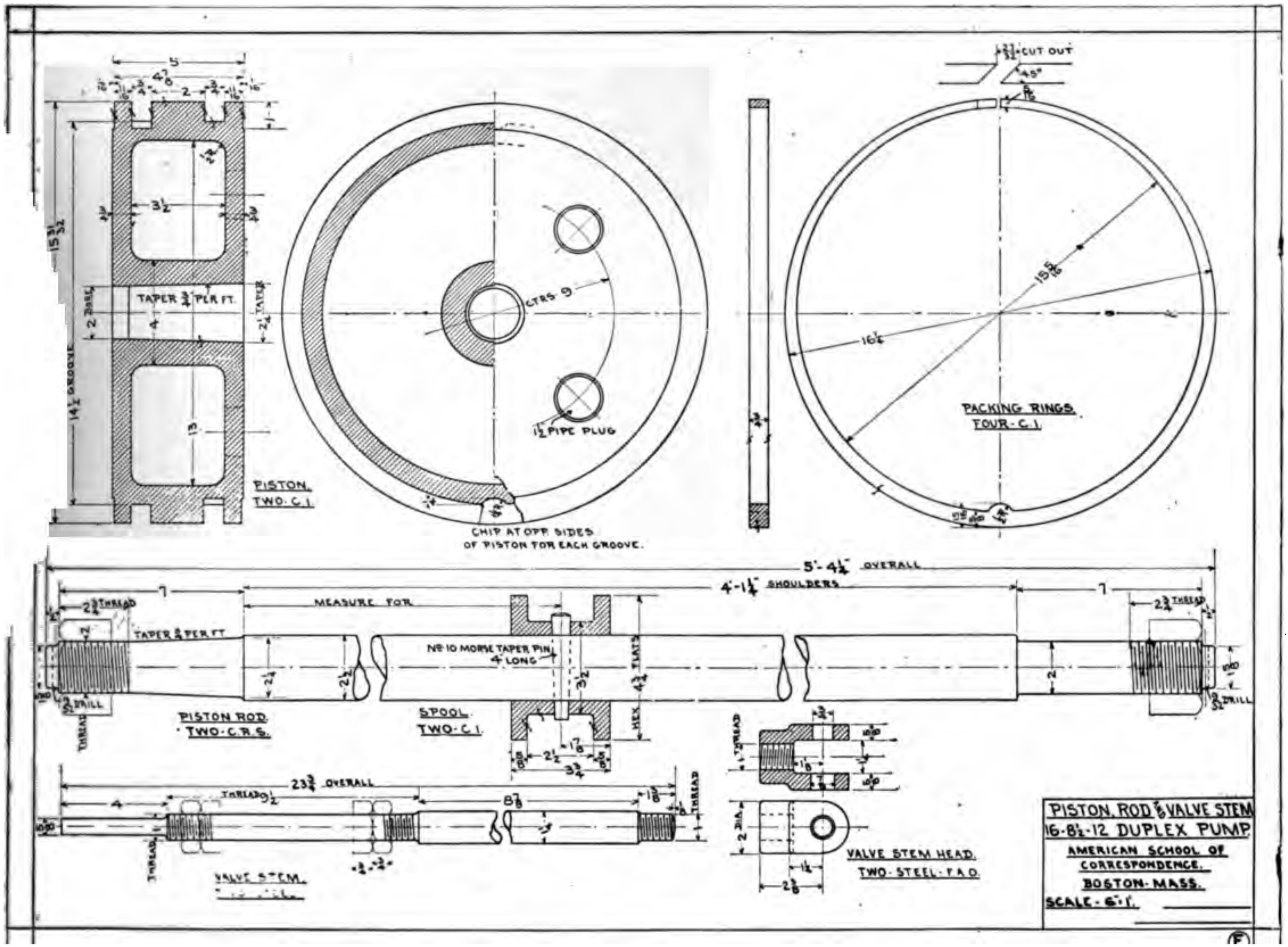
Figures and letters which are broad in proportion to height are easier to make, and have more character. It should never for a moment be forgotten that uniform *height* and *slope* carefully followed will develop character and quickly lead to artistic excellence.

Foot and inch marks are often put after figures according to the common usage. In cases where feet and inches are expressed, thus: 3′ — 6″, or 4′ — 0″, they are, of course, absolutely necessary, and the dash between the figures must be very positively indicated. In cases of inch dimensions alone the marks may be put on if desired, but where there can be no doubt that inches, and not feet, are meant, the inch marks are not necessary. This practice is followed on the plates of this paper.

*Abbreviations.* A list of the most common abbreviations in use on working drawings follows. This list has been adopted for the plates in Part IV:

| | |
|---|---|
| F. A. O. | finished all over. |
| *f.* | finished surface. |
| R. | radius. |
| D. | diameter. |
| R. H. | right hand. |
| L. H. | left hand. |
| P. R. | piston rod. |
| P. TAP. | pipe tap. |
| CTRS. | centers. |
| C. I. | cast iron. |
| S. C. | steel casting. |
| Bz. | bronze. |
| C. R. S. | cold rolled steel. |
| T. S. | tool steel. |
| O. H. S. | open hearth steel. |
| W. I. | wrought iron. |

**Plate E. Piston Rod and Valve Stem.** The piston is of the one-piece box type, with sprung-in rings. The width is reduced to $4\frac{7}{8}$ inches at the outside, so that if the piston strikes the cylinder heads it will not tend to spring and break off the narrow ridge of metal outside of the packing ring. The piston rod is fastened to the piston on a taper drawn in by a nut, and the


PISTON. TWO-C.I.
TAPER 3/4 PER FT.
CHIP AT OPP. SIDES OF PISTON FOR EACH GROOVE.
1 1/2 PIPE PLUG
CTRS 9
PACKING RINGS FOUR-C.I.
CUT OUT
5'-4 1/4" OVERALL
4'-1 1/4" SHOULDERS
MEASURE FOR
No 10 MORSE TAPER PIN 4" LONG
PISTON ROD TWO-C.R.S.
SPOOL TWO-C.I.
HEX 4 3/4 FLATS
23 3/4 OVERALL
VALVE STEM
VALVE STEM HEAD. TWO-STEEL-F.A.O.
PISTON, ROD & VALVE STEM
16-8 1/2-12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE.
BOSTON-MASS.
SCALE-6"-1'.

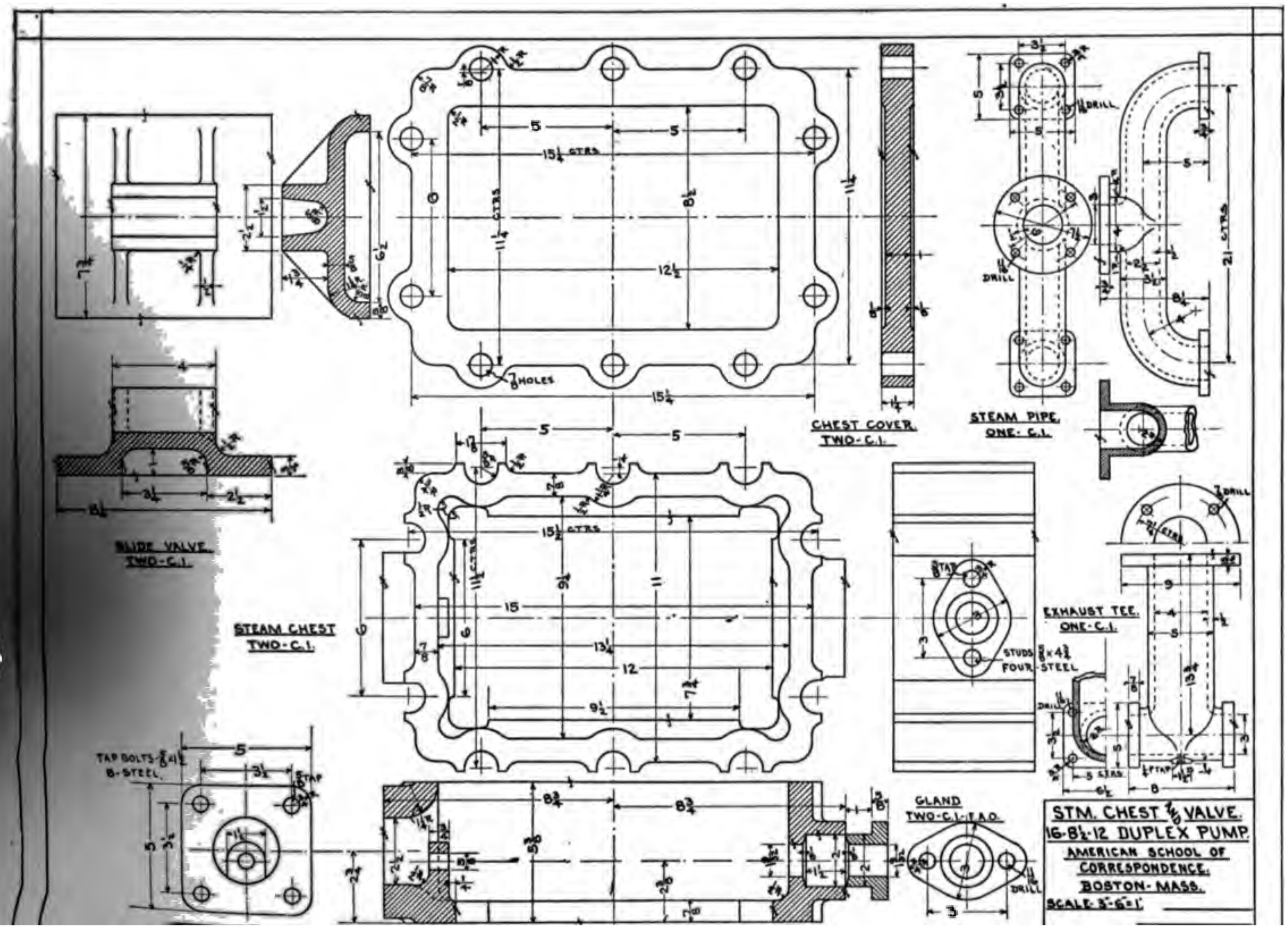
nut is checked by a $\frac{1}{4}$-inch split pin. The packing rings are prevented from slipping round the piston by lugs fitting loosely in chipped recesses in the groove. These being at opposite sides for each groove, the leakage of steam through the split in the ring is minimized, for it must pass half way round the piston before it can pass through the split in the other ring. This is a simple, but fairly effective, device.

The packing rings are usually cast in the form of a cylinder of some length, turned to a diameter a little larger than the cylinder bore, cut off to the required width, and sufficient space cut out to permit being sprung in to the size of cylinder bore.

The location of the spool on the piston rod is not positively known, as the setting of the valve bracket may be slightly different from what the drawing calls for. Hence, instead of a dimension, the words "measure for" are put on, to indicate that the spool be located during the erection of the pump. The hexagonal flanges of the spool are convenient to hold the rod from turning while screwing on the piston and plunger nuts.

*Molding and Machining.* There are no special features connected with the molding and machining of parts on Plate E. The holes in the piston side walls are necessary to give supports for the core, the piston being cast on its side. These holes, after the core is cleaned out through them, are plugged as indicated.

**Plate F. Steam Chest and Valve.** The steam chest in this instance is located on the cylinder by fitting down over the ledge made by the valve seat. The side flanges also serve the purpose of guiding the valve. It will be noticed that the steam chest cover is $15\frac{1}{4}$ inches $\times$ $11\frac{1}{4}$ inches, while the steam chest is 15 inches $\times$ 11 inches. This allows a ledge of $\frac{1}{8}$ inch, all around which the cover overhangs the walls of the chest. The steam cylinder flange in order to correspond must likewise be $15\frac{1}{4}$ inches $\times$ $11\frac{1}{4}$ inches. The reason this is done is because of the difficulty of making good matched joints between the cylinder flange, chest and cover. The practice of thus leaving a little ledge all round is by no means universal, and often the irregularity in the joints is smoothed off by chipping. This is the case with the other flanges on this pump. The steam chest, however, was thought less likely to match properly, and the slight overhang gives the finished appearance of a sort of beaded edge.


SLIDE VALVE.
TWO-C.I.
STEAM CHEST
TWO-C.I.
CHEST COVER
TWO-C.I.
STEAM PIPE
ONE-C.I.
EXHAUST TEE.
ONE-C.I.
GLAND
TWO-C.I.-F.A.O.
STUDS FOUR-STEEL
TAP BOLTS B-STEEL
STM. CHEST AND VALVE.
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF
CORRESPONDENCE.
BOSTON-MASS.
SCALE 3"-6"=1'

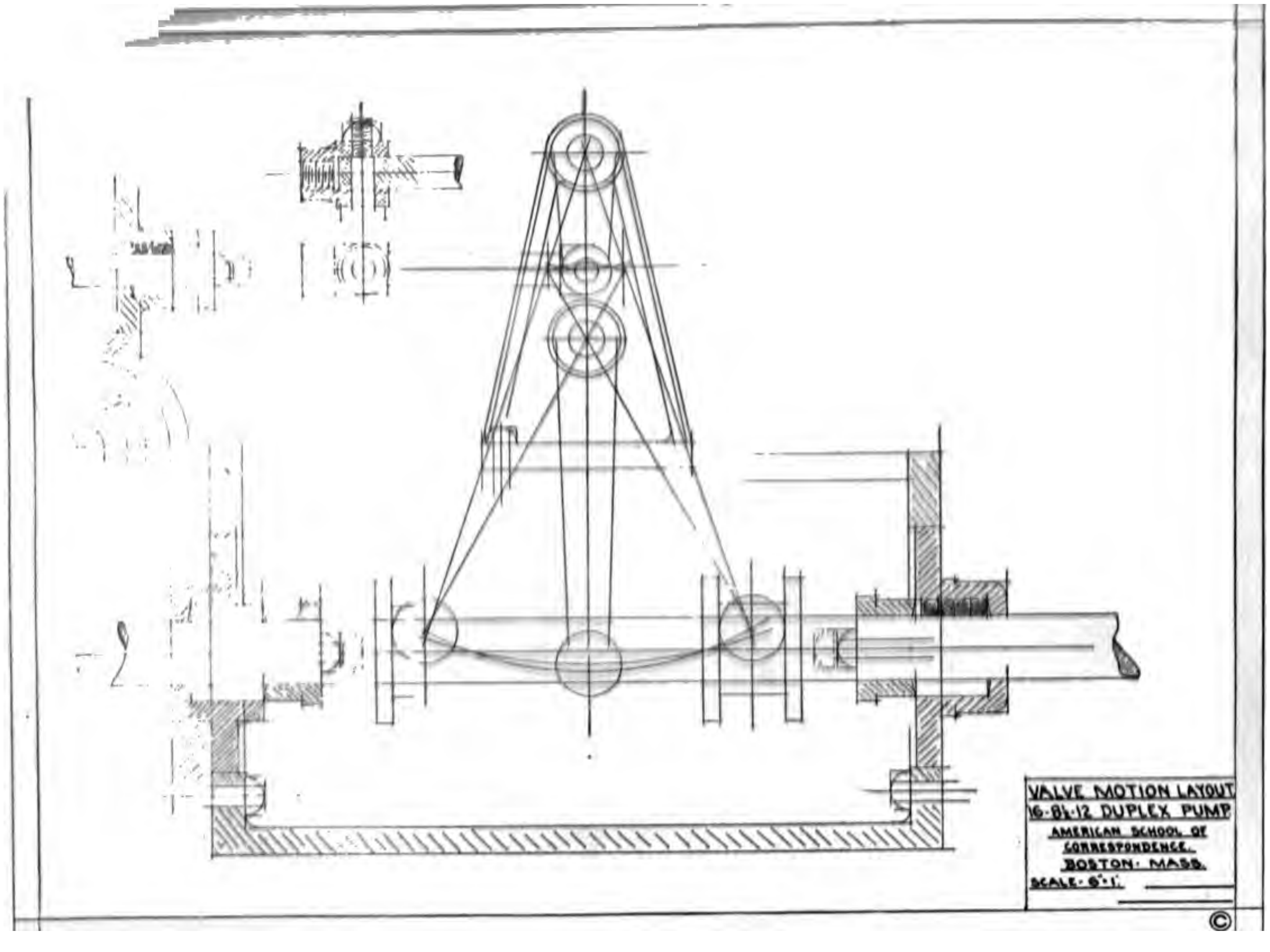
The valve is what is known as a "square" slide valve. This means that when the valve is placed central on the ports its working edges are "square" with the ports; that is, in exact line with them. If the valve be moved either way from this position, the slightest travel will admit steam to one end of the cylinder and exhaust it from the other. (See Plate A.) Another way of stating this is to say that a "square" slide valve is a slide valve without "lap."

The valve is driven from the valve stem by the striking of the nuts against the lug on its top. Since the valve is already guided on its edges by the steam-chest flange, the valve stem, to avoid springing, must be perfectly free in the slot cast for it, as is shown by the $\frac{5}{8}$-inch radius of the bottom, the stem being 1 inch in diameter.

The steam-pipe flange is made square to keep the height of the chest as low as possible. The radius of the bend should be ample; in this case 4 inches is considered sufficient.

The exhaust tee must have its upper flange high enough so that the chest cover can be lifted and slipped off the studs without interfering with it. The lower flanges should be made wide enough to permit the tap bolts to be put in without striking the 4-inch vertical pipe, 5-inch centers being necessary. The $\frac{1}{4}$-inch drip-cock, as located, readily drains the steam chest and exhaust passage of both cylinders, as well as the exhaust tee.

*Molding.* It is evident that the steam chest will be molded in the position shown on the drawing. The parting line of the mold will be through the centers of the steam-pipe opening and the stuffing-box. These holes must be cored out. The main body of the chest could be made to leave its own core, but it may not be made in this way. It may be cheaper to fashion the pattern solid, and make one large core-box for the inside. In this way the pattern will probably hold its shape better and require less repairs, than if it were made in green sand. The core-box will be an extra piece to make, but it probably will cost no more than to carve out the inside of the pattern, and is a rather more substantial job when done. The molding can be satisfactorily done by either method, shop conditions being the controlling element. As far as the labor of molding alone is concerned, the first method is probably easier, as it saves handling large cores.

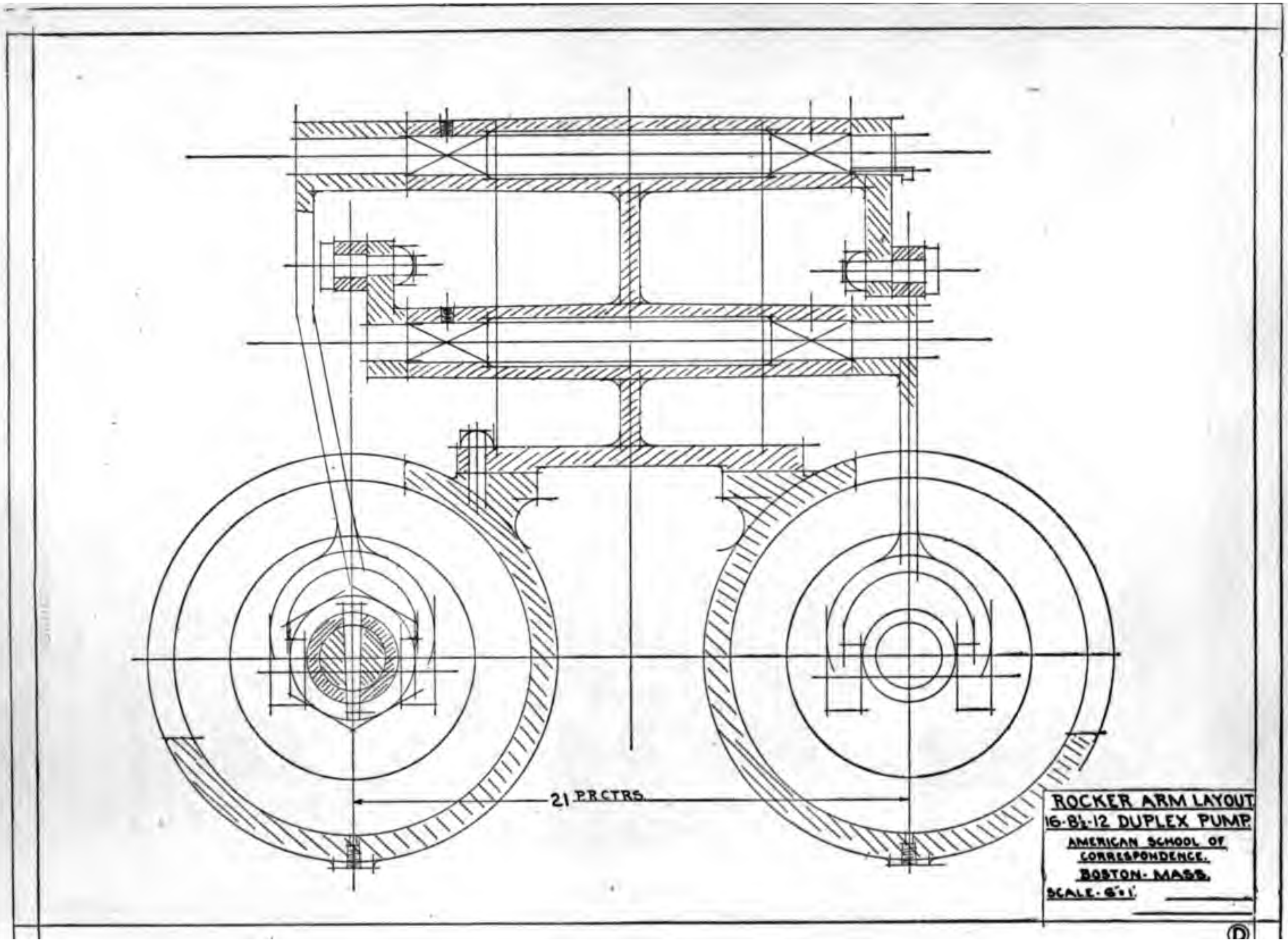

VALVE MOTION LAYOUT
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF
CORRESPONDENCE.
BOSTON. MASS.
SCALE- 6"-1'.
©

The other parts in Plate F are very simple in their molding, and require no special attention.

*Machining.* Most of the surface work on this plate is adapted to the planer. The slide valve may, perhaps, if finished in lots of considerable number, be more satisfactorily handled on the milling machine. The final finish of the face of the valve must be a scraped fit to its seat.

The drilling of the cover and pipe flanges is to actual layout on the casting, or preferably, through jig plates. A templet for laying out is at least desirable, even though the expense of a jig plate be not deemed necessary.

**Plates C and D. Valve Motion Layout.** These plates represent the layout of the valve motion, and are necessary in order to find the length of the levers and rocker arms. It will be noticed in Plate D that the valve stem of one side of the pump is controlled by the movement of the piston-rod of the other side, the proper direction of motion being given to the valve by placing the rocker shaft above or below the valve stem as required. By reference to Plate A it will be further noticed that the nuts on the valve stem inside the chest, which abut against the faces of the lug on the valve, do not rest against the faces of the lug in the position shown, but have considerable lost motion. This lost motion is one of the essential features of the valve motion of a duplex pump, and permits the valve to remain at rest for a short period at the end of the stroke, though the valve stem may have reversed its motion and begun its return stroke. When this lost motion is taken up by the movement of the stem and the nuts abut against the lug on the valve, the valve will move, and from this point to the end of the stroke be positively controlled by the motion of the stem. At the end of the stroke the stem will reverse, when the lost motion will again permit the valve to rest for the same period as at the other end, and then move on as before. The time of rest of the valve, and consequently the pistons and plungers, is approximately one-third the period of the stroke. This means that the piston on one side travels one-third of its stroke before it picks up, through the valve levers, the valve on the other side. During the second third of its travel it is bringing the

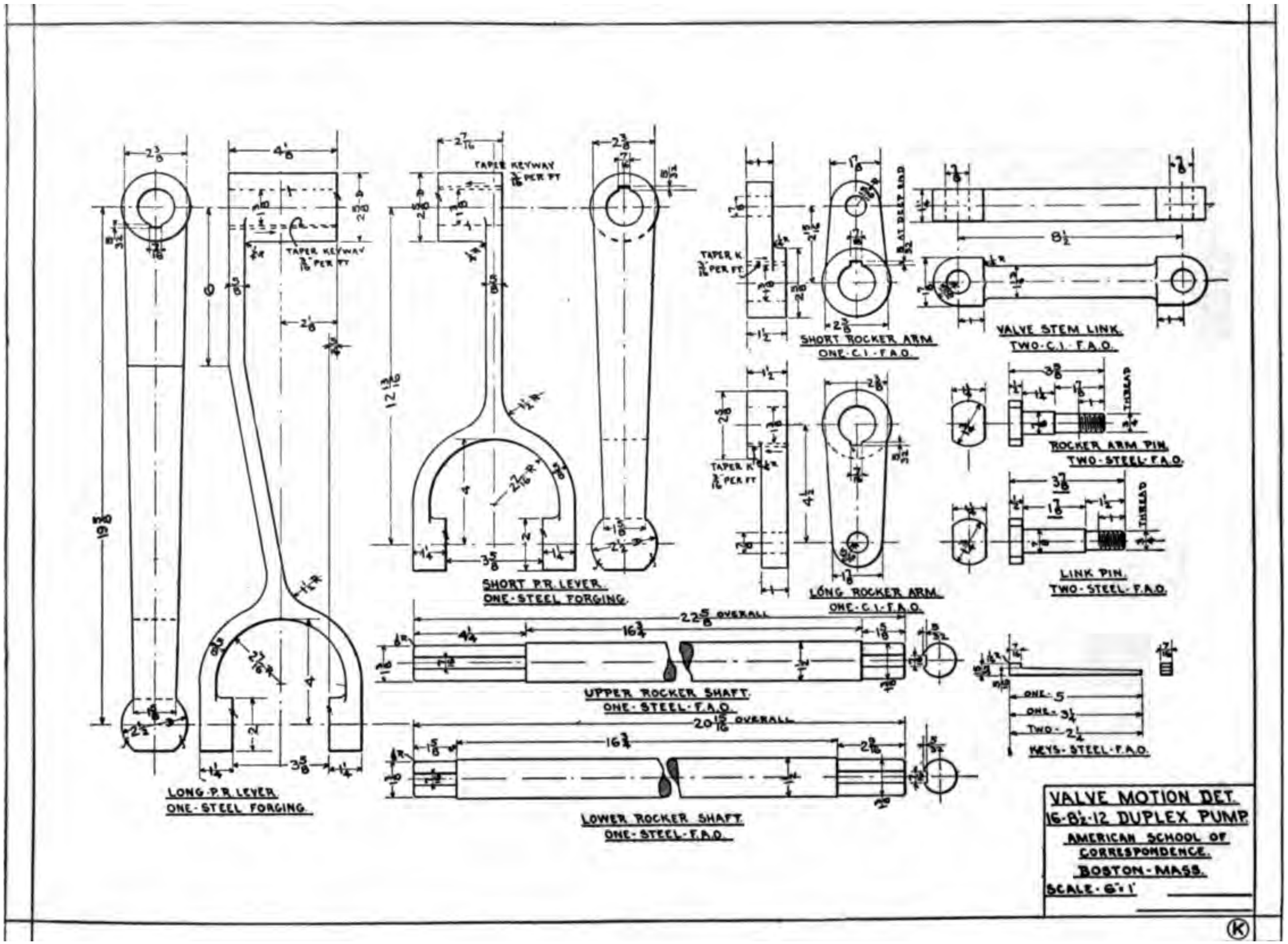

21 P.R.CTRS.
ROCKER ARM LAYOUT
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE.
BOSTON-MASS.
SCALE-6"=1'
D

valve to the point of opening. During the last third of its travel it is opening the port, wider and wider, to steam. Thus the opposite piston will start when the first piston has covered two-thirds of its stroke, and there will be only one-third of the stroke when both pistons are moving at the same time.

This relative period of rest to motion is not always made in this exact ratio, but is at least approximate to it. The period of rest at the end of the stroke is to allow the water end to adjust itself quietly to the reversal of motion about to take place at the end of the stroke. When the plunger stops, the water valves must be given time to seat themselves, and the flow of water through the passages checked. It is much easier to start the flow in the opposite direction if the reversal of plunger motion is not instantaneous. Hence for handling long columns of water, which, once in motion, tend by considerable energy to remain in motion, the duplex pump by this peculiar delayed action has been found to be well suited.

It will be found that for complete uncovering of port, and motion divisible into thirds as described, the travel of the valve stem should be three times the width of port, or $3 \times \frac{7}{8}$ inch $= 2\frac{5}{8}$ inches. A little more than this is allowed, and the travel made $2\frac{7}{8}$ inches in this case. Referring to Plate C, this distance is laid off as shown by the two limiting vertical lines across the line of the valve stem, the central vertical line of mid-position being drawn. The problem then is to find such centers for the rocker arms that the travel of the piston-rod spool will, through proper leverage, produce travel of the valve stem between these two vertical lines. This can readily be done by a few trials, the only requirement for this case being that the extremes of the arc of swing of both piston-rod lever and rocker arm shall be equally above and below the center of piston rod and valve stem respectively. The greatest possible travel of the piston-rod spool, $12\frac{1}{2}$ inches, is usually laid out in this case, not the nominal 12 inches.

From this layout the lengths of the levers and arms may be scaled off for the detail drawing, also the location of the rocker-arm centers. The student has the former given him on Plate K, but the latter, which is necessary for the development of Plate L, must be determined by his own layout. Plate D must also be


LONG P.R. LEVER.
ONE-STEEL FORGING.
SHORT P.R. LEVER.
ONE-STEEL FORGING.
TAPER KEYWAY
SHORT ROCKER ARM
ONE-C.I.-F.A.O.
LONG ROCKER ARM
ONE-C.I.-F.A.O.
VALVE STEM LINK.
TWO-C.I.-F.A.O.
ROCKER ARM PIN.
TWO-STEEL-F.A.O.
LINK PIN.
TWO-STEEL-F.A.O.
UPPER ROCKER SHAFT.
ONE-STEEL-F.A.O.
LOWER ROCKER SHAFT.
ONE-STEEL-F.A.O.
KEYS-STEEL-F.A.O.
VALVE MOTION DET.
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF
CORRESPONDENCE.
BOSTON-MASS.
SCALE-6"=1'
K

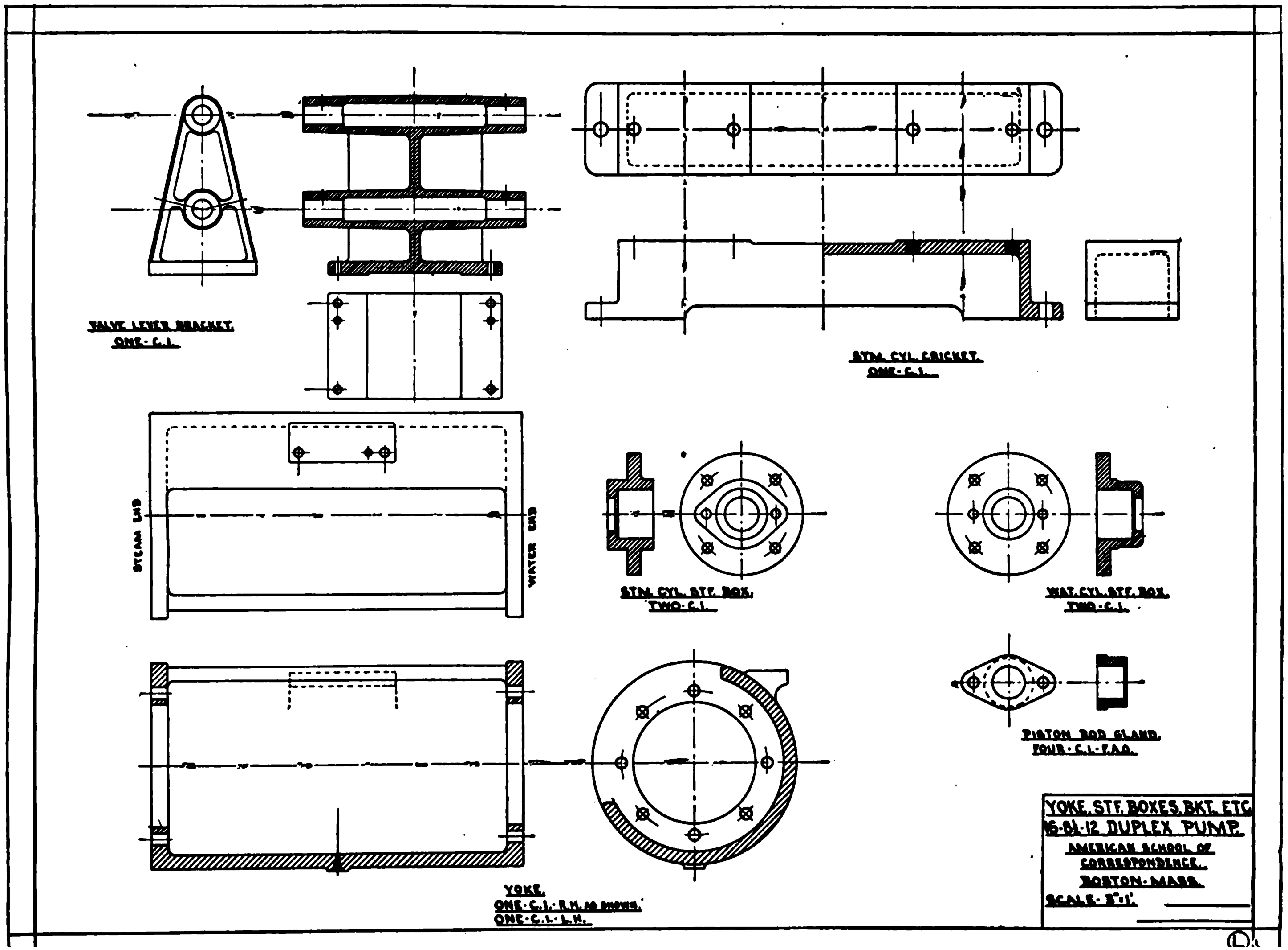
laid out before developing the cross-section of the valve bracket.

The design of stuffing boxes for both steam and water ends, and the length of the yoke, should be determined next. A safe method of assuming clearance between the spool and the gland studs at the end of the stroke, is to imagine that the gland stud nuts have accidentally worked off the studs, so that they are about to drop. They are thus shown by dotted lines on Plate C. A good clearance, say $\frac{1}{4}$ inch to $\frac{1}{2}$ inch, is then allowed, and the gland drawn in. The length of the gland is determined by the number of rings of packing necessary in the stuffing box; it is usually provided that the gland may compress the packing to about one-half its original depth before bringing up against the face of the box. Packing $\frac{5}{8}$ inch square will do for this size of piston rod, hence the faces of the yoke are easily determined, and its detail, with the stuffing boxes, proceeded with as on Plate L. The length of yoke may be brought to an even figure; and proceeding on the above plan the length can be conveniently made in even inches without any fractions; viz., 28 inches.

It will be noticed that the stuffing-box flanges serve to center the yoke in line with the steam and water cylinders. This is a desirable feature of construction, and forms a simple and easy method for lining up the steam and water ends.

**Plate K. Valve Motion Details.** The piston-rod levers on this plate are specified to be steel forgings. Forgings of this kind are expensive, but are light, neat and reliable for the important service which they have to perform. Castings, whether steel or iron, are much cheaper, and perhaps more commonly used for this detail. When sound they are equally serviceable, though of more clumsy proportions; but the danger in castings of this form is the existence of hidden flaws or pockets, which frequently occur at the points where the hub or the fork joins the arm. These flaws cannot be readily detected from the outside, and breakage may occur at some critical time, when the disability of the pump may be a serious matter.

The use of shade lines is illustrated on this plate. The increased artistic effect is noticeable, but it would seem that absolute clearness would still exist, even if shade lines were not used.



VALVE LEVER BRACKET.
ONE - C.I.
STM. CYL. CRICKET.
ONE - C.I.
STEAM END
WATER END
STM. CYL. STF. BOX.
TWO - C.I.
WAT. CYL. STF. BOX.
TWO - C.I.
PISTON ROD GLAND.
FOUR - C.I. - F.A.O.
YOKE.
ONE - C.I. - R.H. AS SHOWN.
ONE - C.I. - L.H.
YOKE, STF. BOXES, BKT. ETC.
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF
CORRESPONDENCE.
BOSTON - MASS.
SCALE - 3" = 1'.

It will be noticed that on the detail of the "link pin" two of the dimensions have a short "wavy" line beneath the figures. This is one of the several ways of indicating that the dimension is "out of scale." Some draftsmen use a straight dash beneath the figure; some draw a circle about it; some print after the figure, "out of scale." Although workmen are not allowed to scale drawings, but are required to "work to figures only," yet for general safety's sake, and for the sake of the draftsmen who consult the drawings frequently, attention must be called to any variation of the figure from the measured distance on the drawing. Nothing makes a workman, or any one else who reads a shop drawing, lose confidence in it more quickly than to discover that it does not "scale"; but when no indication exists that the draftsman himself is aware of it, then every dimension is viewed with doubt and hesitation, and the drawing becomes practically worthless.

Dimensions seldom should be out of scale; but if they are, through error or necessary change, a carefully worded note should be added.

*Molding and Machining.* No special features of molding or machining are noteworthy on Plate K.

**Plate L. Yoke, Stuffing-boxes, Bracket, etc.** Having worked up the layouts of Plates C and D, the student has enough information to proceed with Plate L. This, like Plate G, is without dimensions, the student's work being to make the drawing and fill in the necessary shop data.

The valve-lever bracket is bolted down to its lug on the yoke through holes larger than the bolt, thus permitting slight adjustment. When the proper location is determined, the bracket is positively fixed in position by two dowels, $\frac{1}{2}$ inch in diameter. The holes in both bracket and yoke are drilled through both pieces at the same operation. This very common method of fixing bolted parts of machinery in absolute position not only assures firmness, but also in case of removal, permits the part to be readily and positively replaced in its exact original position.

If possible, the steam cylinder cricket should be of such height that the stone or brick work upon which it rests shall be at the same level as that beneath the water cylinder. The tapped holes in the top surface receive bolts from the cylinder foot. These bolts are often used only for shipping purposes, the cylinder foot when the pump is set up being allowed to slide freely on the cricket, thus permitting free expansion and contraction. In such cases the water end is rigidly fastened to the foundation by holding down bolts.

*Molding and Machining.* The valve lever-bracket would most naturally be molded with the axes of the shafts vertical, the parting line of the mold being the center line of the middle web. This makes quite a long "draw" for the shaft bosses, but the ample taper on the outside overcomes this difficulty. The space between the side webs leaves its own core. The shaft cores stand on end in the mold, which is the best position for strength and stability.

Another method is to have the parting line of the mold on the vertical center line of the bracket, as shown in the end view. In this case the bracket would be cast on its side, and cores must be set for each side of the middle web. The shaft cores are set as easily as before, but in this case lie flat. As with the steam chest, each method has its advantages, which depend largely upon existing conditions. As cored work is generally avoided whenever possible, the first method would probably be chosen.

The shaft bosses are "chamber-cored," to save labor in boring, the bearing surface for the shaft being only a short distance at the ends. The chamber-core diameter should be enough larger than the shaft so that by no possibility can the cutter run into the rough scale, even if the hole be bored slightly out of line. If it should do this, the labor of caring for the cutters more than offsets the attempted saving of labor.

The yoke is simply a barrel open at each end, and with a piece cut out of its side. The inside evidently must be cored out, and the core is satisfactorily supported at the ends on its horizontal axis. The parting line of the mold may be either the vertical or horizontal axis of the end view, the only difference being that in one case the ledge for the valve bracket will "draw," and in the other case it must be loose on the pattern and "pulled in" after the main pattern is drawn.

The cricket and stuffing boxes present no difficulties. The bore of the stuffing boxes and glands should be from $\frac{1}{32}$ inch to $\frac{1}{16}$ inch larger than the rod, to allow the fit to be entirely between the rod and the packing.

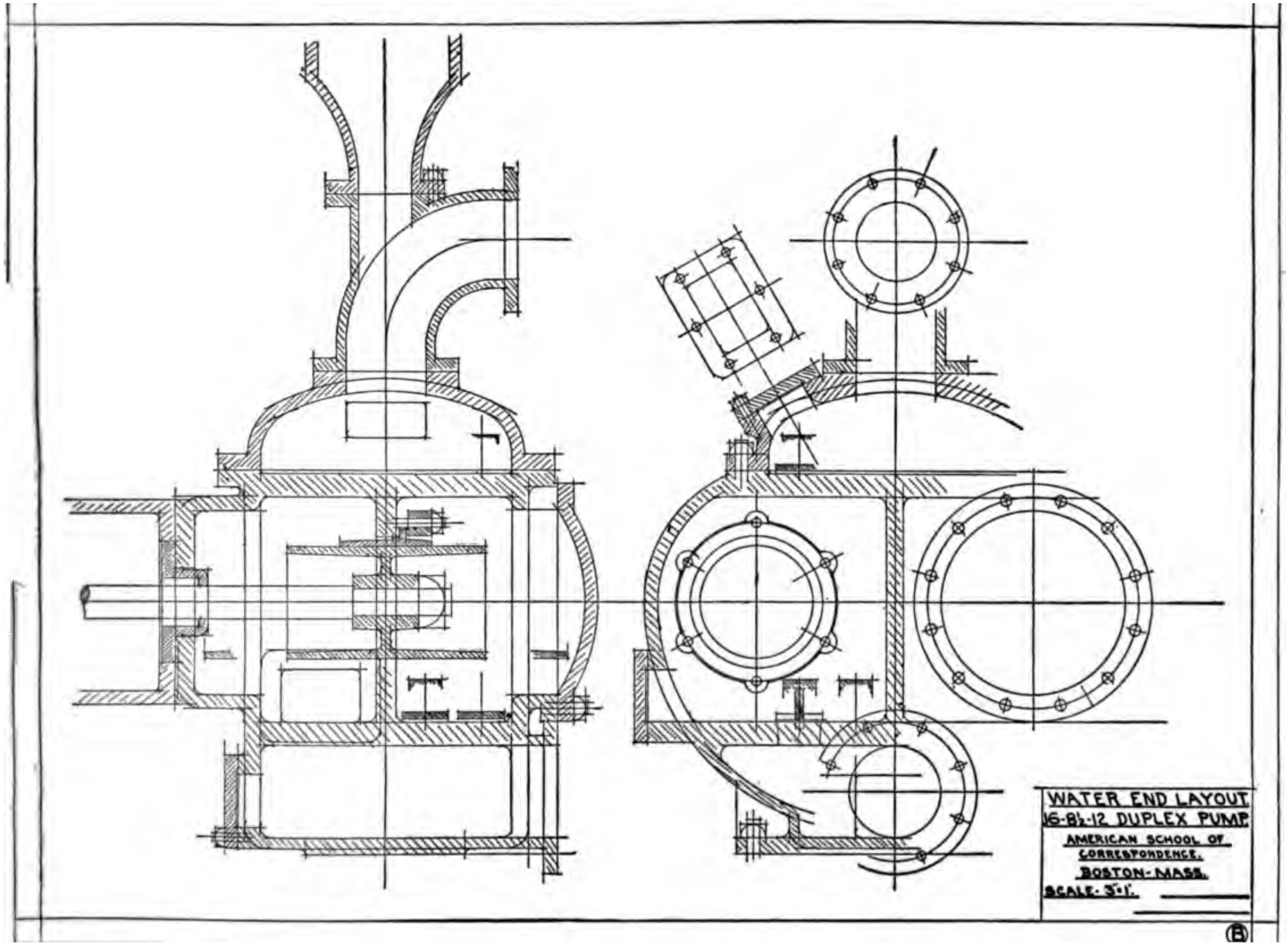
The horizontal boring machine with a double facing head is adapted to boring and facing the yoke flanges. The drilling is accomplished as before by templet or jig.

Attention is called to the tapped holes for oil or grease cups on the valve-lever bracket. The holes on the lower boss cannot be drilled strictly as shown, because the drill shank will not clear the upper boss. They should be swung around the boss at such an angle as will allow the drill to clear. This is a good instance of the common error of drawing details which cannot be made, and constant watch must be kept to avoid such mistakes.

**Plate B. Water End Layout.** As in the preceding work, Plates H and I being given in full detail offer a good start for the development of the water cylinder, which is the purpose of Plate B. As before, work should begin at the inside and progress outwards. Thus the piston rod with its nut should be drawn first, the hub of the plunger built around it, then the plunger barrel, the bushing, and ring to clamp the bushing. The limits of the plunger travel should be sketched in, and the valve outline shown in order to determine clearances. The progress of Plate B is on exactly the same basis as that stated in detail for the steam cylinder layout; hence it need not be repeated.

The points controlling the design of the water end must, however, be studied to enable the student to work intelligently. The fit of the rod into the plunger hub is loose, $\frac{1}{16}$-inch play being allowed, in order to permit the plunger to be guided solely by its bushing, and thus be independent of any change of alignment of the piston rod.

The relative length of plunger and bushing should allow the end of the plunger to overrun the edge of the bushing at the termination of the stroke, to prevent the formation of a shoulder. The bushing is made of brass because of the better bearing of the two dissimilar metals, brass and iron. Of course there is no lubrication except the water, and the dissimilar metals tend to "cut" less than if both were alike. The brass bushing also prevents the plunger from "rusting in" in case of long periods of


WATER END LAYOUT
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF
CORRESPONDENCE,
BOSTON-MASS.
SCALE- 3"=1'.
B

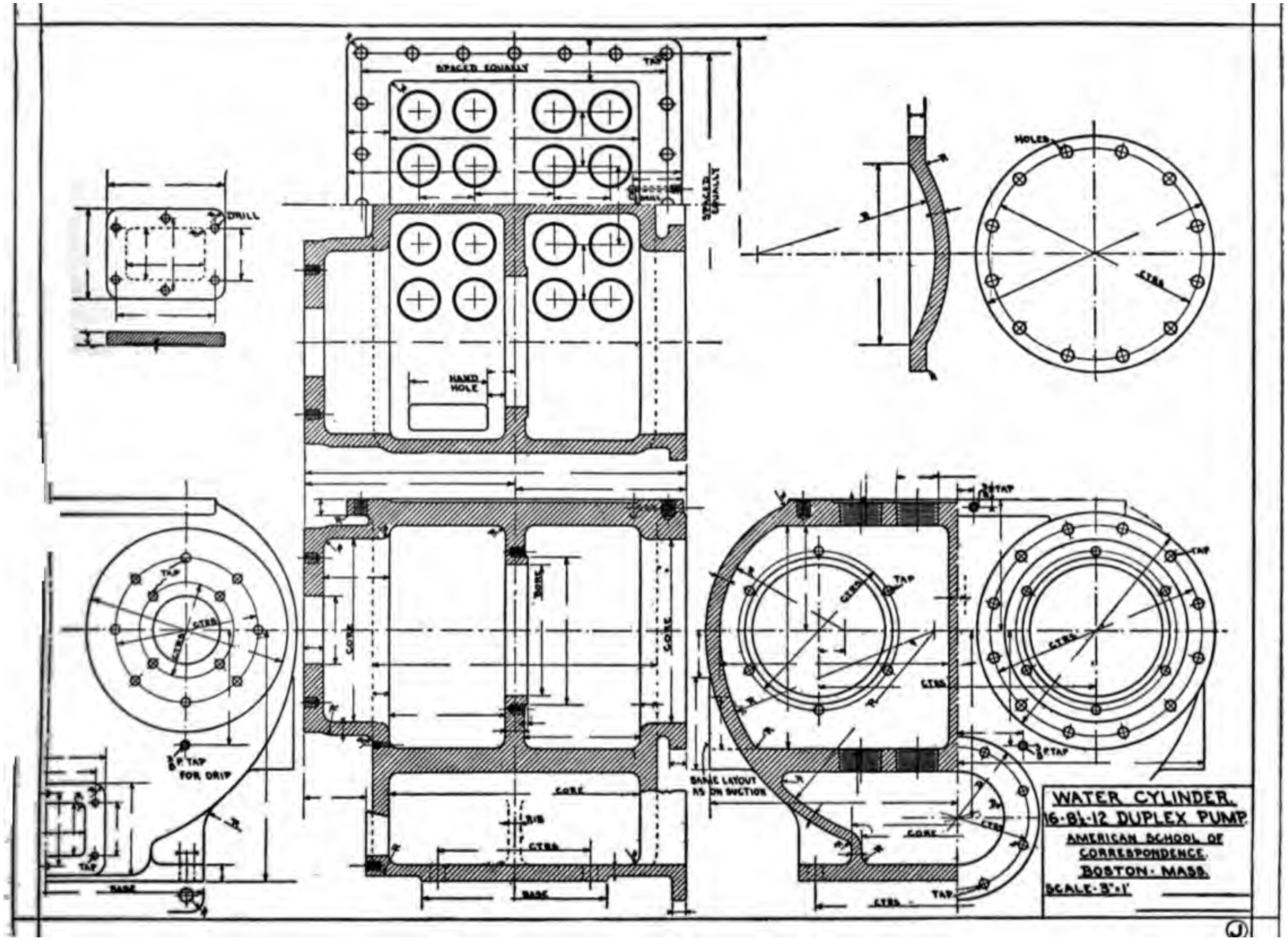
disuse. The bushing being of expensive material is made as light as possible, hence it has no stiffness of its own. Therefore it is reinforced by a deep cast-iron ring, which also takes the bolts and clamps the bushing tightly to its ground seat. These stud bolts are usually made of "tobin bronze," a rust-proof material, possessing strength almost as great as that of steel. This arrangement permits ready removal of the bushing when necessary.

As the parts of the common pump valve illustrated in detail on Plate H must be often replaced during service of the pump, provision must be made for unscrewing the stem and substituting a new one. This must be done through the hand holes provided on the cylinder. The lower valve deck must be located so that the inner valves when unscrewed will not strike the clamp ring. As shown in Plate B the clearance is pretty small, almost too small, but as it affects only two valves, it will probably cause no inconvenience. No hand holes are necessary for the end chambers, as access to the valves is had by removing the outer heads. The upper deck may be placed at a height giving sufficient clearance to allow the upper nuts of the clamp ring to be unscrewed with a socket wrench from the end of the pump. These decks are subjected to a severe pounding from the pulsations of the pump, and should be amply strong; $1\frac{3}{4}$ inches is deemed thick enough for this case.

The middle transverse wall may be $1\frac{1}{2}$ inches thick and the middle longitudinal wall a little thinner, about $1\frac{1}{4}$ inches. With high pressures these walls, being flat surfaces and the valve decks likewise, are likely to fracture under the heavy pounding. To avoid making them excessively heavy they are often strongly ribbed, either on the inside or outside, usually the former.

The curving side walls are of better form to withstand pressure, and need not be as thick, 1 inch being sufficient. This can be decreased to $\frac{3}{4}$ inch in the suction passage below the deck, where little pressure exists.

The outer head is also considered strong enough at 1 inch thickness, on account of its curved shape. It requires $\frac{7}{8}$-inch studs. Studs are preferred to tap bolts in this case, as in all other similar cases, on account of the frequent unscrewing of the nuts for purpose of removal. One or two unscrewings of a tap bolt in cast


WATER CYLINDER.
16·8½·12 DUPLEX PUMP.
AMERICAN SCHOOL OF CORRESPONDENCE.
BOSTON · MASS.
SCALE · 3" = 1'
SPACED EQUALLY
HAND HOLE
DRILL
HOLES
CORE
BORE
CTRS
RIB
BASE
TAP
⅜" P. TAP FOR DRIP
BASE LAYOUT AS ON SUCTION
J

iron will destroy the tightness of the thread, while the stud, being steel, stands the wear better.

The valve seats are taper screwed into the deck; they are sometimes forced in on a plain taper fit. They are located as closely as strength of the deck between the holes will permit. It is not well to place the edge of the valve closer than $\frac{1}{2}$ inch from the cylinder walls. The valve holes in the lower deck should be in line, or nearly so, with the holes in the upper deck, in order to allow the shank of the mill to pass through when milling the lower holes.

The suction opening is 7 inches in diameter, $12\frac{1}{2}$-inch flange, $10\frac{1}{2}$-inch bolt circle, $\frac{3}{4}$-inch tapped holes.

By means of the hand hole at the end of the suction passage, any dirt which may have been brought in through the suction pipe may be removed.

The water cylinder cap, discharge ell and air chamber may be laid out from the detail Plate I, and the student must do this to see that the parts actually go together properly.

With the foregoing discussion the student should be able to produce Plate B, which is the preliminary step to the detail drawing of the water cylinder as shown on Plate J.

**Plate J. Water Cylinder.** The water cylinder is, perhaps, the most complicated detail that the student will meet in this set of plates. Fundamentally, it is simply a box with curved sides, divided by the several walls into five compartments, each of which communicates with the outside by a round nozzle or flange. If this basic idea be kept constantly in mind, the student will have no trouble in building up the detailed design.

This fundamental conception of a complicated piece is a very important idea, and should be developed carefully by the student. It is one of the great secrets of good design, both from an artistic and a commercial standpoint. We often see a machine which seems to begin anywhere and end nowhere; it appears to be a miscellaneous collection of bosses, lugs, ribs and flanges. There is no general prevailing shape to the structure, no harmony of the lines. This is because the designer, if he may be so called, did not have the fundamental notion of shape, to which all minor details should have been subordinated. He simply grouped parts together, without considering the fundamental structure.

In this water cylinder the box is the basic part of the structure, and its lines must be first developed; they should be designed to convey a smooth, regular and consistent surface to the eye. Then the nozzles and flanges may be added as subordinate parts; they will merely interrupt, but not destroy, the prevailing outline of the box. The dotted lines in the cross-section views of Plate J show the general shape behind and beneath the nozzles.

The hand holes are the same as on Plate I, and the detail of the cover should specify the number required for both places.

Provision for draining the four chambers of the water cylinder is made by the $\frac{3}{8}$-inch pipe tap holes at the lower deck, and the cap, likewise, by the single hole at the upper deck. Drip cocks are screwed into these holes.

The holding-down bolts should not be less than 1 inch diameter; $1\frac{1}{4}$ inch would perhaps be better; and the holes in the foot should be drilled at least $\frac{1}{8}$ inch large.

*Dimensions.* It will be noticed that this plate has dimension lines, but no figures. This is because the cylinder is rather difficult to figure, and it is desired to guide the student in arrangement of the figures without lessening the benefit of his study of them. Special attention should be paid to this feature of the plate. Notice that although space for dimensions is restricted, a clear opening is always found for the figures; and when one view seems to offer no space for a figure, another view gives the desired opportunity.

No finish marks or titles are shown on this plate, these being left entirely to the student for insertion.

*Molding.* The centers of the curves for the sides being on the main horizontal axis of the nozzles, the cylinder, if molded to be cast vertically as shown, will draw readily both ways from this line. The exceptions to this easy draw are the foot, suction nozzle and flange, and hand-hole boss. On account of the inside of the cylinder being cored, these pieces if made loose on the pattern have ample space to be "pulled in" after the main pattern is withdrawn.

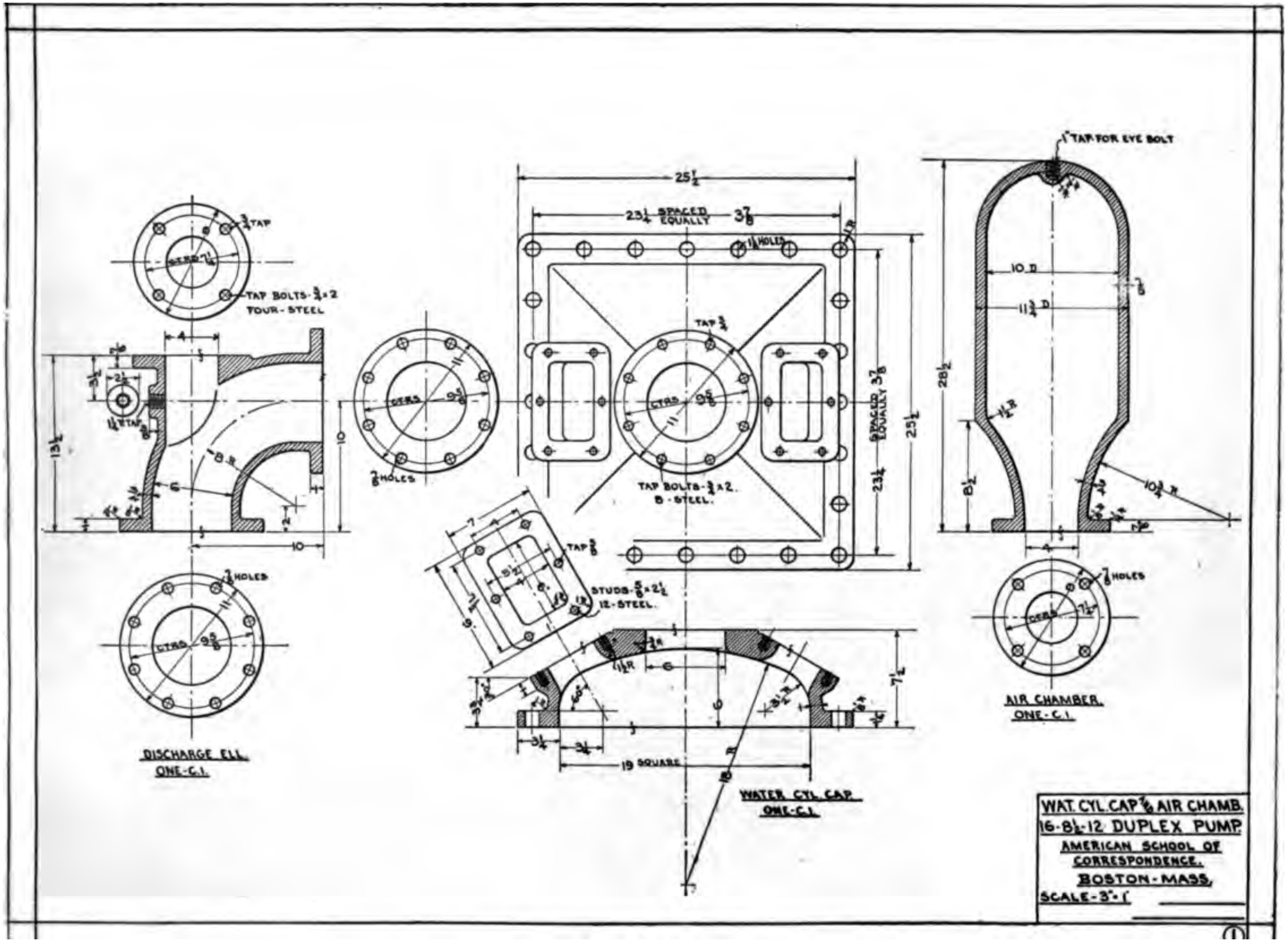
The suction passage below the deck communicates with the main core through the valve holes, hence it may be supported from the main core. This involves some difficulty, however. If a three-part flask be used, and another parting established at the center of the suction flange, in addition to the previous one, the problem becomes much simplified.

It is desirable to make the four chambers of the cylinder alike in general proportions. It is then possible to make a single core-box, and by the use of loose pieces change the length of the nozzle cores and transpose from right to left, thus saving labor on the pattern. This, however, multiplies the loose pieces on the pattern. The many pieces are likely to become lost and make frequent repair necessary. Hence it is not always wise to use a single core box too much, and good judgment is required to fix the limit.

*Machining.* Special double horizontal boring machines are now in common use for such cases as this water cylinder. The centers are made adjustable, so that within limits any distance between piston-rod centers can be met. The advantages of double boring are, of course, most obvious for a considerable number of duplicate cylinders.

It will be noticed that the face of the suction flange is carried out flush with the cylinder head face. This affords opportunity for finishing all the end surfaces at a single setting of the tool, whether the work be done on the rotary or reciprocating planer. This same point might have been observed on the small hand-hole boss at the other end of the cylinder, but the advantage gained did not seem to warrant extending the "reach" through the hand hole.

**Plate I. Water Cylinder, Cap and Air Chamber.** For a water cylinder cap of this size, the most difficult problem is to find room for the hand-hole bosses. A hand hole 4 inches × 6 inches is about as small as can be used, and this calls for a flange at least 7 inches × 9 inches. These are the proportions shown on the plate, and since the boss overhangs the bolts in the main-cap flange, it must be cut away underneath to clear the nuts. If three stud bolts are used on each side, this overhang also requires that the nut be "fed on"; that is, screwed on little by little as the end of the stud protrudes above the flange when the cap is being lowered into place. This is an awkward process, but is sometimes necessary.



DISCHARGE ELL.
ONE-C.I.
TAP BOLTS-3/4×2
FOUR-STEEL
WATER CYL. CAP.
ONE-C.I.
TAP BOLTS-3/4×2.
8-STEEL.
STUDS-5/8×2 1/4
12-STEEL.
19 SQUARE
AIR CHAMBER.
ONE-C.I.
1" TAP FOR EYE BOLT
WAT. CYL. CAP'S & AIR CHAMB.
16-8 1/2-12 DUPLEX PUMP.
AMERICAN SCHOOL OF
CORRESPONDENCE.
BOSTON-MASS.
SCALE-3"-1'

The discharge ell should have an easy bend; usually the radius is somewhat more than the outside diameter of the pipe, in this case 50 per cent greater. It is customary on this piece to provide an opening for the attachment of a relief valve as shown, 1¼-inch pipe tap. This valve can be set to open at a desired pressure, so that the water end may be relieved in case of accidental excessive pressure.

The air chamber provides an air cushion for the water to make the delivery more constant, and take the shock which would otherwise come with hammer-like force and full intensity upon the cylinder. Being placed at the highest point of the water end, air will naturally tend to collect in the air chamber and keep it charged. In some cases, however, a special charging device is necessary.

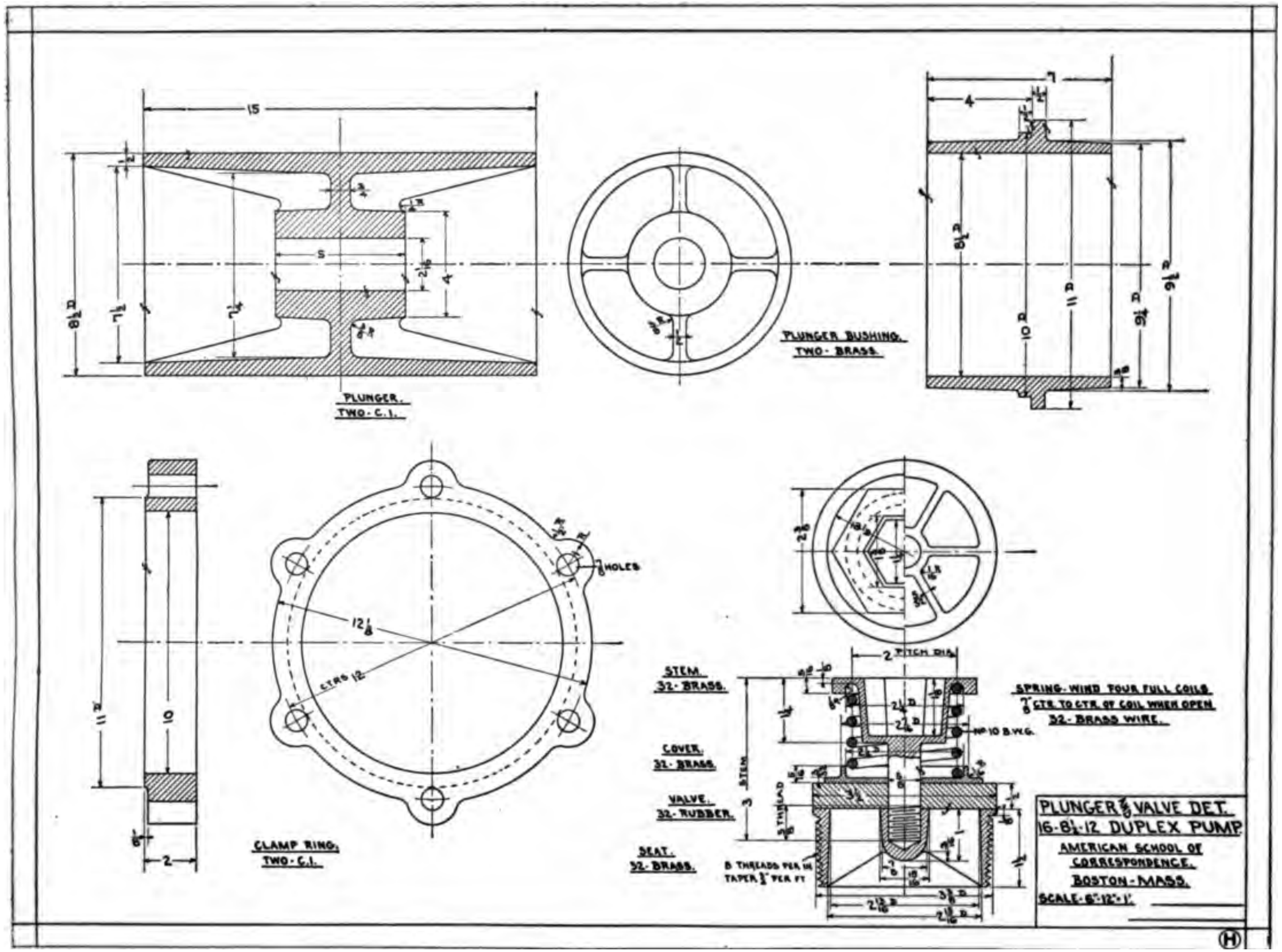
*Molding and Machining.* The hand holes being at an angle will not "draw." Hence cores must be set for these openings at least, and it may be desirable to core out the whole inside of the cap for the sake of keeping the pattern in good shape by making it solid. Otherwise it is easy to let it leave its own core.

The overhang of the hand-hole bosses requires loose pieces for the overhanging part. They are "pulled" in after the pattern is drawn.

The molding and machining which are further required on details of Plate I are simple, and require no special discussion.

**Plate H. Plunger and Valve Details.** This plate is noticeable for illustrating a method of drawing details not used elsewhere in this set of plates. On the other plates each piece is separately detailed. On Plate H the details of the valve, cover, seat, stem and spring are shown assembled, and dimensioned without separation. This is an allowable method when clearness is not sacrificed, but it is usually found desirable only with simple construction. It concentrates parts on the drawing, and probably saves some time, besides showing the workman just how the parts go together. The only test which the student need to apply in this, as in any method of detailing, is the test for absolute clearness.

It is believed in the case of the valve as shown that the details are completely illustrated without sacrificing clearness. Special care in putting in dimensions is of necessity required.


PLUNGER.
TWO - C.I.
PLUNGER BUSHING.
TWO - BRASS.
CLAMP RING.
TWO - C.I.
HOLES
STEM.
32 - BRASS.
COVER.
32 - BRASS.
VALVE.
32 - RUBBER.
SEAT.
32 - BRASS.
8 THREADS PER IN
TAPER ¾" PER FT
PITCH DIA.
No 10 B.W.G.
SPRING - WIND FOUR FULL COILS
⅞" CTR TO CTR OF COIL WHEN OPEN
32 - BRASS WIRE.
PLUNGER & VALVE DET.
16 - 8½ - 12 DUPLEX PUMP
AMERICAN SCHOOL OF
CORRESPONDENCE.
BOSTON - MASS.
SCALE - 6" = 12" = 1'
H

The valve stem can be unscrewed either with a socket wrench on the inside or an ordinary fork wrench on the outside.

The seat, after being screwed to position in the deck, is often faced off, to true up any distortion caused by screwing in.

The valve itself, of rubber, can be bought of any desired grade of hardness. The specification for any given set of valves depend upon the quality of the water, the pressure and the general service of the pump.

*Molding and Machining.* By reason of the simple nature of the parts on this plate, the molding and machining is left entirely to the original consideration of the student.

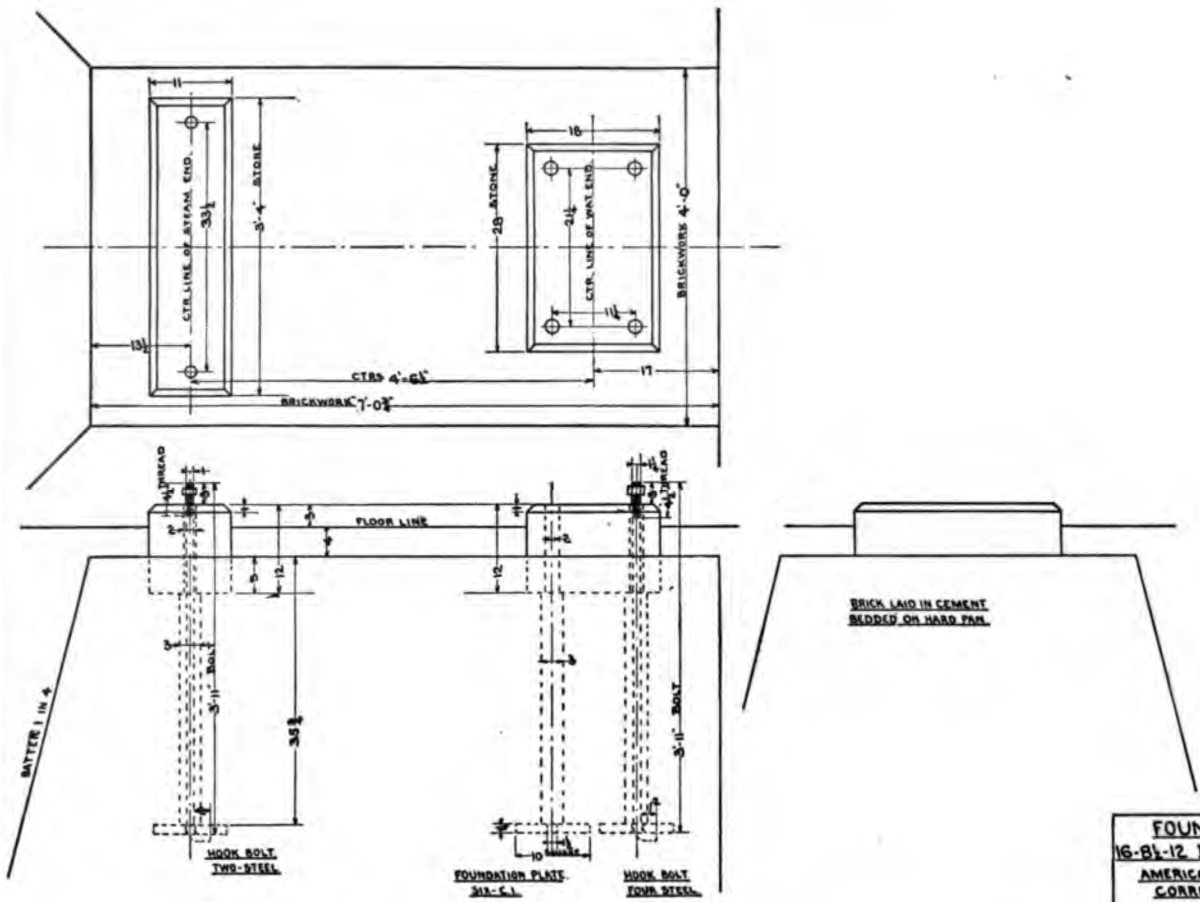
**Plate M. Foundation.** Pumps are often set directly upon a foundation of brick, but it makes a better job to bed stones, with surfaces dressed plane and true, into the main foundation, and rest the pump feet upon these stones. The simplest form of holding down bolts are shown on Plate M, a plain hook at the lower end, pulling up against a flat cast-iron plate, to distribute the pressure into the brickwork. These plates are of course bedded, and the bolts set as the foundation is built up. As the subsequent courses are laid some little space is left around the bolts, which may be afterwards filled with cement, thus making the bolts rigid with the foundation.

The water end of the foundation has no batter, because the suction pipe often drops vertically down from the end of the pump, and clearance is therefore necessary.

The floor line is placed 4 inches above the brickwork, to allow for the usual 1-inch top floor and 2-inch plank beneath, and still have a space left for shims to level the floor.

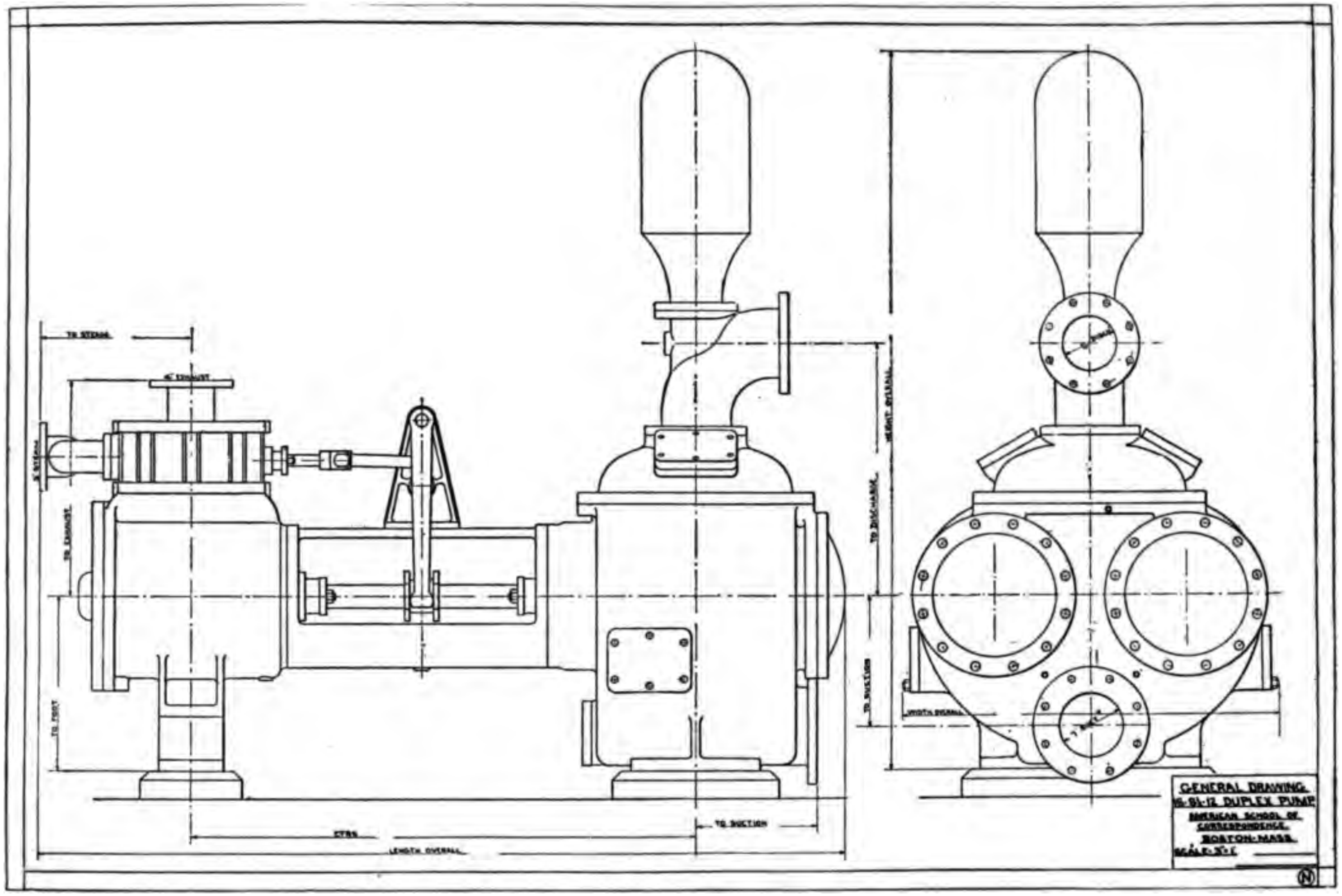
**Plate N. General Drawing.** This is an example of a plain, everyday shop drawing, to show the relation of parts and the extreme space occupied by the pump. A great deal of time can be needlessly wasted in producing a drawing of this character, by trying to make too faithful a picture. For example: If all the bolt heads were put in, it is safe to say that several hours' extra time would be required for this one item alone. But the drawing would be no better for shop use. Hence all bolt heads and nuts have been left out, except when necessary to show clearance.

Shade lines have been put on for no special reason except




FOUNDATION.
16-$8\frac{1}{2}$-12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE.
BOSTON-MASS.
SCALE-$1\frac{1}{2}$"=1'.

(M)


TO STEAM
EXHAUST
TO EXHAUST
TO FOOT
CTRS
LENGTH OVERALL
TO SUCTION
TO DISCHARGE
HEIGHT OVERALL
WIDTH OVERALL
GENERAL DRAWING
DUPLEX PUMP
AMERICAN SCHOOL OF
BOSTON-MASS.

that if they are desirable on any drawing they are especially desirable on a general drawing, where one part overlaps another, as they make it easier to pick out and separate one surface from another. Some lines are shaded in this drawing which are not strictly sharp edges. It is held, however, that the rounding of a corner ought not to destroy its character as an edge casting a shadow, and such lines are treated accordingly.

An assembled or general drawing of this character should be laid out strictly from the dimensions shown by the details. It thus serves a valuable purpose in checking up figures, and showing whether or not the parts will go together. The method or character of the work in no respect differs from that suggested for the detail drawings.

If a scale of 3 inches = 1 foot be used, the size of sheet must be 24 inches × 36 inches. The student, however, will perhaps find it easier to use a scale of $1\frac{1}{2}$ inches = 1 foot, in which case the ordinary size, 18 inches × 24 inches, will suffice. For such a small scale it will be found undesirable to attempt to put in any very small fillets and corners, although those that can be readily handled by the ordinary bow pen ought not to be omitted. As a matter of fact, the expert draftsman either leaves the corners sharp, as suggested, or puts in the smallest curves freehand.

**Order Sheets.** Any set of drawings is incomplete unless in connection with it a statement is made in tabular form of the complete make-up of the machine. An infinite variety of ways exists for making the specifications. Sometimes the tabulated data are placed on the general drawing. Most often, however, printed blanks are provided, usually of bond paper, arranged with special reference to the individual shop system and methods of handling work; these blanks are filled in by the draftsman, indexed and filed as a part of the set of drawings. They can be blue printed for use in the shops the same as a drawing. From these sheets stock is ordered, checked off, and watched in its process of manufacture.

Order sheets are indispensable in any well-ordered shop. Hence they are illustrated on pages 59, 60, 61 and 62 as the final step in the set of pump drawings. They are made as simple as possible, and are not intended to fit any special shop system. As previously stated, the exact form and method of classification can be determined only when the shop conditions are known.

The student, having carefully followed through the preceding pages, must not think that he is master of pump construction, for even the type illustrated has been but touched upon. The object of the detailed discussion is to get the student in close touch with the spirit of construction, to make his drawings real serious work. It is hoped that the student will work just as though a machine were to be built from his drawings, and built to sell at a profit. Only in this way can advanced work in mechanical drawing be of benefit to him, for after becoming expert in the use of the instruments, no other advance is possible except advanc in *thought*.

DATE.
MAY 20, 1902.

AMERICAN SCHOOL OF CORRESPONDENCE
AT
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.

TYPE.
INSIDE PLUNGER.

LIST OF CASTINGS

FOR

16–8½–12 DUPLEX PUMP.

| No. Wanted. | Name. | Drawing No. | Patt. or Piece No. | Material. | Remarks. |
|---|---|---|---|---|---|
| 2 | Steam Cylinder | G | | C. I. | R. & L. |
| 2 | Steam Cylinder Head | G | | C. I. | |
| 2 | Steam Chest | F | | C. I. | |
| 2 | Steam Chest Cover | F | | C. I. | |
| 2 | Slide Valve | F | | C. I. | |
| 1 | Steam Pipe | F | | C. I. | |
| 1 | Exhaust Tee | F | | C. I. | |
| 2 | Valve Steam Gland | F | | C. I. | |
| 2 | Piston | E | | C. I. | |
| 8 | Piston Pipe Plug, 1½″ | E | | C. I. | |
| 4 | Piston Packing Ring | E | | C. I. | |
| 2 | Spool | E | | C. I. | |
| 1 | Steam Cylinder Cricket | L | | C. I. | |
| 2 | Steam Cylinder Stuffing Box | L | | C. I. | |
| 2 | Water Cylinder Stuffing Box | L | | C. I. | |
| 4 | Piston Rod Gland | L | | C. I. | |
| 1 | Valve Lever Bracket | L | | C. I. | |
| 2 | Yoke | L | | C. I. | R. & L. |
| 1 | Short Rocker Arm | K | | C. I. | |
| 1 | Long Rocker Arm | K | | C. I. | |
| 2 | Valve Stem Link | K | | C. I. | |
| 1 | Water Cylinder | J | | C. I. | |
| 2 | Water Cylinder Head | J | | C. I. | |
| 5 | Hand Hole Cover | J | | C. I. | |
| 1 | Water Cylinder Cap | I | | C. I. | |
| 1 | Air Chamber | I | | C. I. | |
| 1 | Discharge Ell | I | | C. I. | |
| 2 | Plunger | H | | C. I. | |
| 2 | Plunger Bushing | H | | Brass | |
| 2 | Clamp Ring | H | | C. I. | |
| 32 | Valve Stem | H | | Brass | |
| 32 | Valve Cover | H | | Brass | |
| 32 | Valve Seat | H | | Brass | |
| 6 | Foundation Plate | M | | C. I. | |

DATE.
MAY 20, 1902.

AMERICAN SCHOOL OF CORRESPONDENCE
AT
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.

TYPE.
INSIDE PLUNGER.

LIST OF STEEL AND MISCELLANEOUS PARTS

FOR

16–8½–12 DUPLEX PUMP.

| No. Wanted. | Name. | Drawing No. | Patt. or Piece No. | Material. | Remarks. |
|---|---|---|---|---|---|
| 2 | Valve Steam Head | E | | St. | Drop Forging. |
| 2 | Piston Rod | E | | C. R. S. | |
| 2 | Valve Stem | E | | St. | |
| 1 | Long P. R. Lever | K | | St. | Forging |
| 1 | Short P. R. Lever | K | | St. | Forging |
| 1 | Upper Rocker Shaft | K | | St. | |
| 1 | Lower Rocker Shaft | K | | St. | |
| 2 | Rocker Arm Pin | K | | St. | |
| 2 | Link Pin | K | | St. | |
| 1 | Long P. R. Lever Key | K | | St. | Drop Forging |
| 1 | Short P. R. Lever Key | K | | St. | Drop Forging |
| 2 | Rocker Arm Key | K | | St. | Drop Forging |
| 32 | Valve Spring | H | | Brass wire | Spring Temper |
| 32 | Valve | H | | Rubber | Medium |
| | | | | | |
| | | | | | |
| | | | | | |

| DATE. MAY 20, 1902. | AMERICAN SCHOOL OF CORRESPONDENCE AT ARMOUR INSTITUTE OF TECHNOLOGY CHICAGO, ILL. | TYPE. INSIDE PLUNGER. |
|---|---|---|

LIST OF BOLTS, NUTS AND PINS

FOR

16—8½—12 DUPLEX PUMP.

| No. wanted. | Name. | | Drawing No. | Patt. or Piece No. | Material. | Remarks. |
|---|---|---|---|---|---|---|
| 12 | Cylinder Head | Stud ⅞ x 3¼ | G | | St. | |
| 20 | Steam Chest | Stud ¾ x 8¾ | G | | St. | |
| 4 | Valve Stem Gland | Stud ⅝ x 4¾ | F | | St. | |
| 8 | Piston Rod Gland | Stud ¾ x 4 | L | | St. | |
| 24 | Water Cylinder Head | Stud ⅞ x 3¼ | J | | St. | |
| 12 | Clamp Ring | Stud ¾ x 4⅛ | J | | Tobin bz. | |
| 24 | Water Cylinder Cap | Stud 1 x 3⅛ | J | | St. | |
| 18 | Hand Hole Cover | Stud ⅝ x 2½ | J | | St. | |
| 12 | Hand Hole Cover | Stud ⅝ x 2½ | I | | St. | |
| 8 | Exhaust Tee | Tap Bolt ⅝ x 1¾ | G | | St. | |
| 16 | Yoke | Tap Bolt ¾ x 2 | G | | St. | |
| 8 | Steam Cyl. Stf. Box | Tap Bolt ¾ x 1¾ | G | | St. | |
| 8 | Steam Pipe | Tap Bolt ⅝ x 1⅛ | F | | St. | |
| 4 | Valve Lever Bracket | Tap Bolt ⅝ x 1¾ | F | | St. | |
| 4 | Steam Cyl. Cricket | Tap Bolt 1 x 2¼ | F | | St. | |
| 16 | Yoke | Tap Bolt ¾ x 2 | J | | St. | |
| 8 | Water Cyl. Stf. Box | Tap Bolt ¾ x 1¾ | J | | St. | |
| 8 | Discharge Ell | Tap Bolt ¾ x 2 | I | | St. | |
| 4 | Air Chamber | Tap Bolt ¾ x 2 | I | | St. | |
| 2 | Hook Bolt (special) | 1 x 3′—11″ | M | | St. | |
| 4 | Hook Bolt (special) | 1¼ x 3′—11″ | M | | St. | |
| 1 | Eye Bolt | Standard 1″ | I | | St. | |
| 34 | Standard Nut | ⅝ | | | St. | |
| 44 | Standard Nut | ¾ | | | St. | |
| 36 | Standard Nut | ⅞ | | | St. | |
| 26 | Standard Nut | 1 | | | St. | |
| 4 | Standard Nut | 1¼ | | | St. | |
| 4 | Standard Nut | 2 | | | St. | |
| 8 | Special Valve Stem Nut | 1 | | | St. | ⅝ Thick |
| 4 | Piston Rod Split Pin | ¼ x 2 | E | | St. | |
| 2 | Spool Taper Pin | No. 10 Morse Taper | E | | St. | 4″ long |
| 4 | Valve Bracket Dowel Pin | ⅜ x 2 | L | | St. | |

DATE.
MAY 20, 1902.

AMERICAN SCHOOL OF CORRESPONDENCE
AT
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.

TYPE.
INSIDE PLUNGER.

LIST OF SPECIAL FITTINGS, WRENCHES, ETC.

FOR

16–3½–12 DUPLEX PUMP.

| No. Wanted. | Name. | | Drawing No. | Patt. or Piece No. | Material. | Remarks. |
|---|---|---|---|---|---|---|
| 4 | Drip Cock | ⅛″ | G | | | |
| 1 | Drip Cock | ¼″ | F | | | |
| 2 | Drip Cock | ¼″ | L | | | |
| 4 | Oil Cup | ¼″ | L | | | |
| 5 | Drip Cock | ⅜″ | J | | | |
| 1 | Relief Valve | 1¼″ | I | | | 175 lbs. pressure |
| | | | | | | |
| 1 | Standard Fork Wrench | [illegible] | | | | |
| 1 | Standard Fork Wrench | ¾″ | | | | |
| 1 | Standard Fork Wrench | ⅞″ | | | | |
| 1 | Standard Fork Wrench | 1″ | | | | |
| 1 | Socket Wrench | ¾″ | | | | 12″ handle |
| 1 | Valve Stem Fork Wrench | | | | | |
| 1 | Valve Stem Socket Wrench | | | | | |
| | | | | | | |
| | | | | | | |

## PLATES.

The plates of Part VI (A to N, inclusive,) are so arranged and described that the complete set may be made by the student. In case of insufficient time, the following short examination is prescribed. The student in any case should read carefully all the text, and follow the discussion of all the plates, whether or not actually produced by him.

### PLATE XXV.

Reproduce Plate E (page 32), putting on shade lines. Size of plate to be 18 inches × 24 inches, trimmed, with border $\frac{1}{2}$ inch from edge; size within border line, 17 inches × 23 inches.

### PLATE XXVI.

Make steam end layout, Plate A (page 10). This is to be done accurately *in pencil.* Size same as Plate XXV.

### PLATE XXVII.

Make drawing of steam cylinder, Plate G (page 18), complete, with finish marks and dimensions. Do not put on shade lines.

### PLATE XXVIII.

Draw valve motion layout, Plate C (page 36). This plate also is to be done accurately *in pencil.*

### PLATE XXIX.

Make rough freehand sketches in pencil of parts on Plate L (page 42), putting on finish marks and dimensions. Use a medium pencil, and make sheet of regular size (18 inches × 24 inches). Arrangement to be similar to Plate L. Do not try to make the sketches to scale, but make them sufficiently complete so that detail drawings can be made from them.

### PLATE XXX.

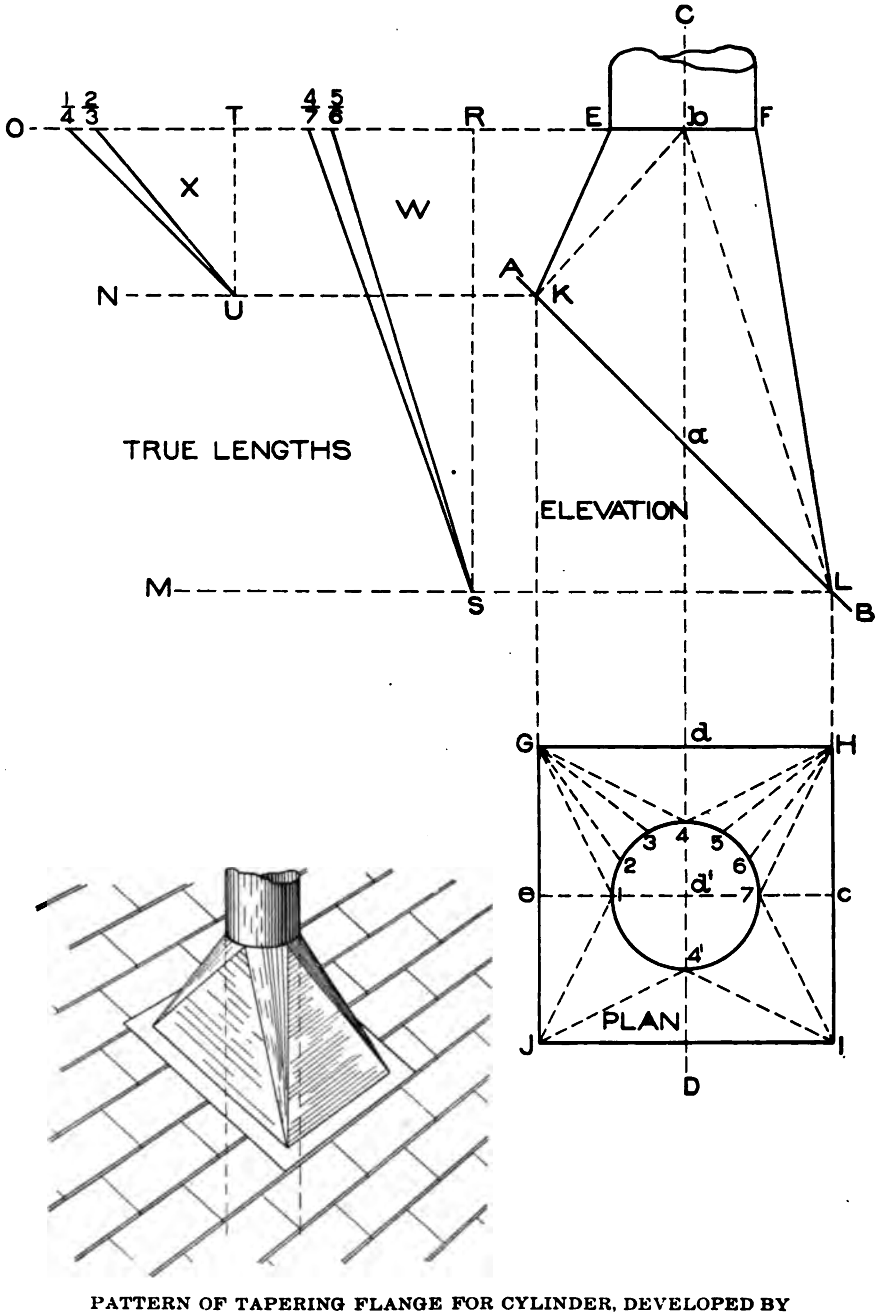
Make a tracing on tracing cloth of Plate E (page 32).

### PLATE XXXI.

Make general drawing Plate N. Use scale of $1\frac{1}{2}'' = 1'$, or $3'' = 1'$.

### PLATE XXXII (Optional).

Make drawing of water cylinder, Plate J (page 48).




PATTERN OF TAPERING FLANGE FOR CYLINDER, DEVELOPED BY TRIANGULATION.

# TINSMITHING.

An important part of the technical education of those connected with tinsmiths' work is a knowledge of laying out patterns. When making the various forms of tinware, or, as they are commonly called, housefurnishing goods, the greatest care must be taken in developing the patterns, for if a mistake of but one point is made, the pattern will be useless. There are general geometrical principles which are applied to this work which, when thoroughly understood, make that part plain and simple, which would otherwise appear intricate. These principles enable the student to lay out different patterns for various pieces of tinware where the methods of construction are similar.

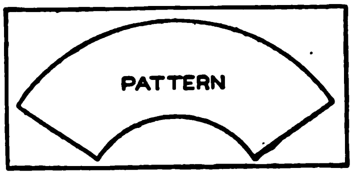


Fig. 1.

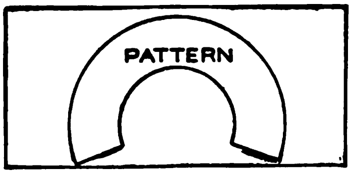


Fig. 2.

**Construction.** Before laying out the pattern for any piece of tinware, the method of construction should be known. Knowing this, the first thought should be: Can the pattern be developed and cut from one piece of metal to advantage, as shown in Fig. 1, or will it cut to waste, as shown in Fig. 2? Will the articles have soldered, grooved or riveted seams, as shown respectively by A, B and C, in Fig. 3? Also, will the edges be wired or have hem edges at the top, as shown respectively by A and B, in Fig. 4? Sometimes the pattern can be laid out in such a way that the article may be made up of two or more pieces, so that the patterns may be laid in one another, as shown in Fig. 5, thereby saving material. This is a plan that should always be followed if possible.

When the patterns are developed, tin plate should be obtained of such size as to have as little waste as possible.

By means of the table on pages 45–47 tin plate may be ordered which will cut to advantage, for there is nothing worse in a tin-shop than to see a lot of waste plate under the benches, whereas a little foresight in ordering stock would have saved material.

**Capacity of Vessels.** Sometimes the tinsmith is required to make a piece of tinware which will hold a given quantity of liquid. The methods of finding the dimensions are given in Arithmetic and Mensuration, which subjects should be reviewed before beginning this work.

**Shop Tools.** The most important hand tools required by the tinsmith are: hammer, shears, mallet, scratch awl, dividers and soldering coppers. The other tinsmith tools and machines will be explained as we proceed.

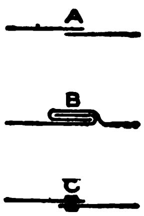



Fig. 3.

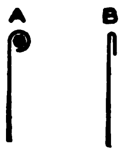



Fig. 4.

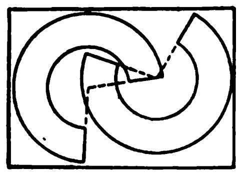


Fig. 5.

**Various Methods of Obtaining Patterns.** The pattern drafting for this course is divided into two classes:

1. Patterns which are developed by means of parallel lines.
2. Patterns which are developed by means of radial lines.

The principles which follow are fundamental in the art of pattern cutting and their application is universal in tinsmiths' work.

## INTERSECTIONS AND DEVELOPMENTS.

The laying out of patterns in tinsmiths' work belongs to that department of descriptive geometry, known as development of surfaces, which means the laying out flat of the surfaces of the solids, the flat surfaces in this case being the tinplate. In Fig. 6 is shown one of the most simple forms to be developed by parallel lines, that of an octagonal prism. This problem explains certain fixed rules to be observed in the development of all parallel forms, which are as follows:

1. There must be a *plan*, *elevation* or other view of the article to be made, showing the line of joint or intersection, and

in line with which must be drawn a section or profile of the article. Thus, ABCD shows the view of the article, AL the line of joint or intersection, and E the profile or section of the article.

2. The *Profile* or section (if curved) must be divided into equal spaces (the more spaces employed the more accurate will be the pattern), from which lines are drawn parallel to the lines of the article intersecting the line of joint or intersection. Thus from the corners numbered 1 to 8 in the profile E, lines are drawn

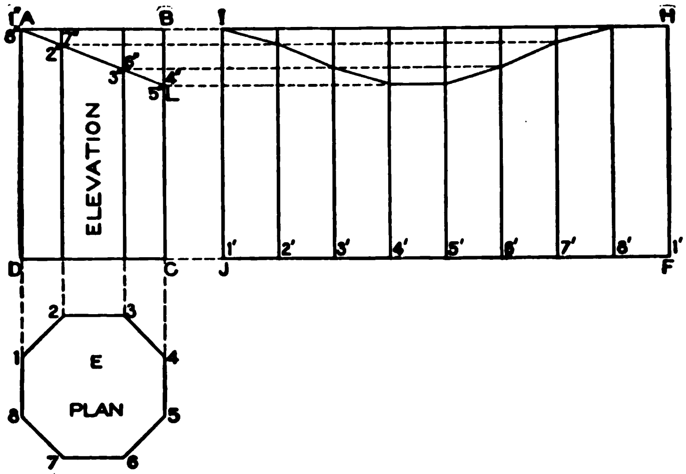



Fig. 6.

parallel to the line of the article, intersecting the line of joint AL from 1″ to 8″. In Fig. 7, where the section A is curved, this is divided into equal spaces.

3. A *stretchout* line (showing the amount of material the article will require) is next drawn at right angles to the line of the article, upon which is placed each space contained in the section or profile. Thus JF, in Fig. 6, is the stretchout line, which contains the true amount required to enclose the profile E.

4. At right angles to the stretchout line, and from the intersections thereon, draw lines called the *measuring lines*. Thus, from the intersections 1′ to 8′ on JF lines are drawn at right angles to the stretchout line JF, which are called measuring lines.

5. From the intersections on the line of joint draw lines intersecting similarly numbered measuring lines, which will result in the pattern shape. Thus lines drawn from the intersections on

the line AL at right angles to BC intersect similarly numbered measuring lines as shown. Then JIIIF will be the development for an octagonal prism intersected by the line AL in elevation.

This simple problem shows the fundamental principles in all parallel-line developments. What we have just done is similar to taking the prism and rolling it out on a flat surface. Let the student imagine the prism before him with the corners blackened

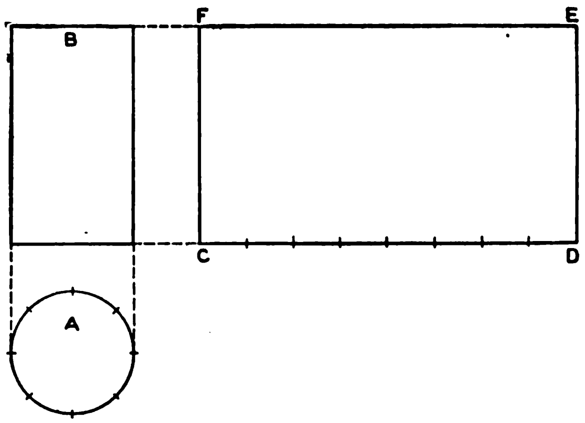



Fig. 7.

and starting with corner 1 turn the prism on a sheet of white paper until the point 1 is again reached, when the result will correspond to the development shown. Bearing these simple rules in mind, the student should have no difficulty in laying out or developing the forms which will follow.

Fig. 7 shows the development of a cylinder, and also shows the principles which are applied in spacing circular sections or profiles, as explained for parallel developments. A shows the profile or section, B the elevation, and CD the stretchout line or the amount of material required to go around the circle. By drawing the measuring lines CF and DE and connecting them by the line FE, we obtain CDEF, which is the development of the cylinder.

Fig. 8 shows how to obtain the development of the surfaces of an intersected hexagonal prism, the angle of intersection being 45°. First draw the elevation ABCD and the section E in its proper position below. Number the corners in the section 1, 2 and 3, as shown, from which erect perpendicular lines intersecting the plane AB, as shown by 1°, 2° and 3°. Bisect the lines 1—1 and 3—3 in plan obtaining the points F and H respectively, and draw the line FH. This line will be used to obtain dimensions with which to construct the developed surface on the plane AB. At right angles to AB and from the intersections 1°, 2° and 3° draw lines as shown. Parallel to AB draw the line $F^v$ $H^v$. Now, measuring in each instance from the line FH in E, take the distances to 1, 2 and 3, and place them on similarly numbered lines drawn from the plane AB, measuring in each instance from the

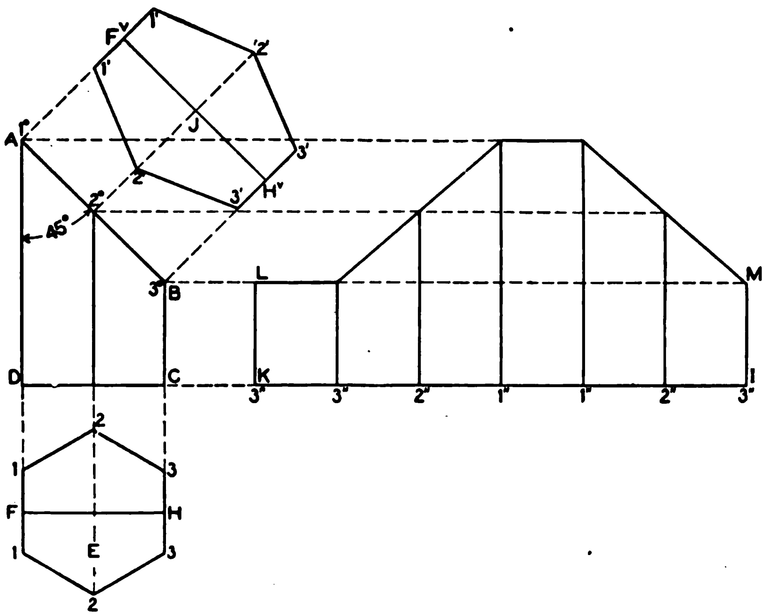



Fig. 8.

line $F^v H^v$ on either side, thus obtaining the points 1′, 2′ and 3′. Connect these points by lines as shown; then J will be the true development or section on AB.

For the development of the prism, draw the stretchout line KI at right angles to AD, upon which place the stretchout of the section E, as shown by similar numbered intersections on KI. From these intersections, at right angles to KI, draw the measuring lines shown, which intersect with lines drawn from similar numbered intersections on the plane AB, at right angles to BC. Through the intersections thus obtained, draw the lines from L to

M. Then KLMI will be the pattern or development of the intersected prism.

Fig. 9 shows the development of an intersected cylinder. A is the elevation and B the profile or plan. As each half of the development will be symmetrical, divide the profile B into a number of equal parts, numbering each half from 1 to 5, as shown. From these points perpendicular lines are erected, intersecting the plane $1^v$ — $5^v$ at $1^v$, $2^v$, $3^v$, $4^v$ and $5^v$. A stretchout is now made of the profile B and placed on the horizontal stretchout line CD, the points being shown by 5′, 4′, 3′, 2′, 1′, 2″, 3″, 4″ and 5″. From

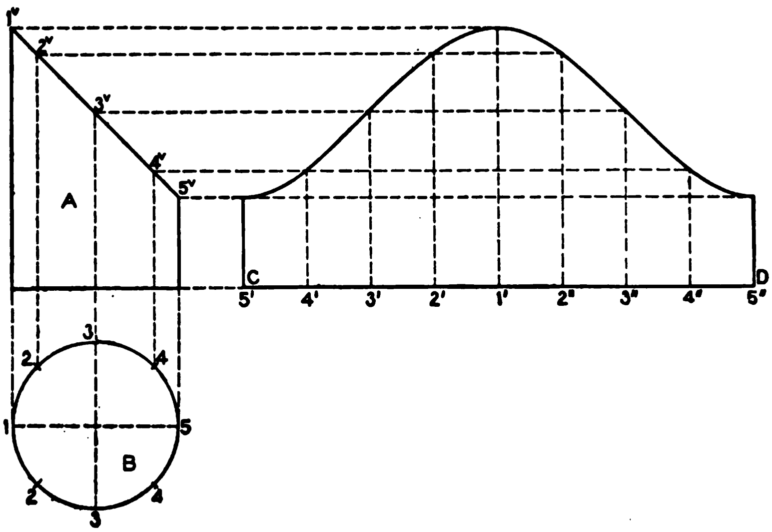



Fig. 9.

these points measuring lines are erected and intersected by similar numbered lines drawn from the plane $1^v$ — $5^v$ at right angles to the line of the cylinder. A line traced through points thus obtained will be the development of the intersected cylinder. In this case the butting edge or joint line of the cylinder is on its shortest side. If the butting edge were desired on its longest side, it would be necessary to change only the figures on the stretchout line CD, making 1′ start at 5′ and end at 5″.

Where two prisms intersect each other, as shown in Fig. 10, it is necessary to find the points of intersection before the surfaces can be developed. Thus we have two unequal quadrangular prisms intersecting diagonally at right angles to each other. We first draw the section of the horizontal prisms as shown by B in the end view, from which the side view A is projected as shown. From the corner T in the section B erect the perpendicular line TC, and above in its proper position draw the section D of the vertical prism, and number the corners 1, 2, 3 and 4. From the corners 1 and 3 drop vertical lines intersecting the profile B at 1′ and 3′, T representing the points 2′ and 4′ obtained from 2 and 4 in D. From the points 1′ and 3′ in B, draw a horizontal line through the side view, and locate the center of the vertical prism as 3″, from which erect the perpendicular line 3″ — 1. Now take a duplicate of the section D and place it as shown by F, allowing it to make a quarter turn (90°); in other words, if we view the vertical prism from the end view, the point 1 in section D faces the left, while if we stood on the right side of the end view the point 1 would point ahead in the direction of the arrow. The side view therefore represents a view standing to the right of the end view, and therefore the section F makes a quarter turn, bringing the corner 1 toward the top. From points 2 and 4 in section F drop vertical lines intersecting the line drawn from the corner 2′ — 4′ in B, thus obtaining the intersections 2″ — 4″ in the side view. Draw a line from 4″ to 3″ to 2″, which represents the intersection between the two prisms.

To develop the vertical prism, draw the horizontal stretchout line HI, and upon it place the stretchout of the profile D as shown by similar figures on HI. Draw the measuring lines from the points 1, 2, 3, 4, 1, at right angles to HI, which intersects with lines drawn at right angles to the line of the vertical prism from intersections having similar numbers on B. A line traced through the points thus obtained, as shown by HILJ will be the development of the vertical prism. The development of the horizontal prism with the opening cut into it to admit the joining of the vertical prism is shown in Fig. 11, and is drawn as follows: Draw any vertical line $O^v$ $P^v$, and on this line place the stretchout of the upper half of section B in Fig. 10, as shown by similar letters and figures in Fig. 11. From these points at right angles to $O^v$ $P^v$ draw lines equal in length to the side view in Fig. 10. Draw a line from U to T in Fig. 11. Now, measuring from the line RS in side view in Fig. 10, take the various distances to points of in-

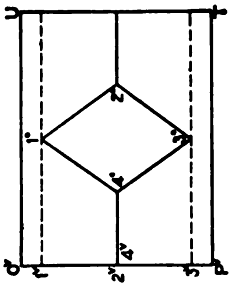


Fig. 11.

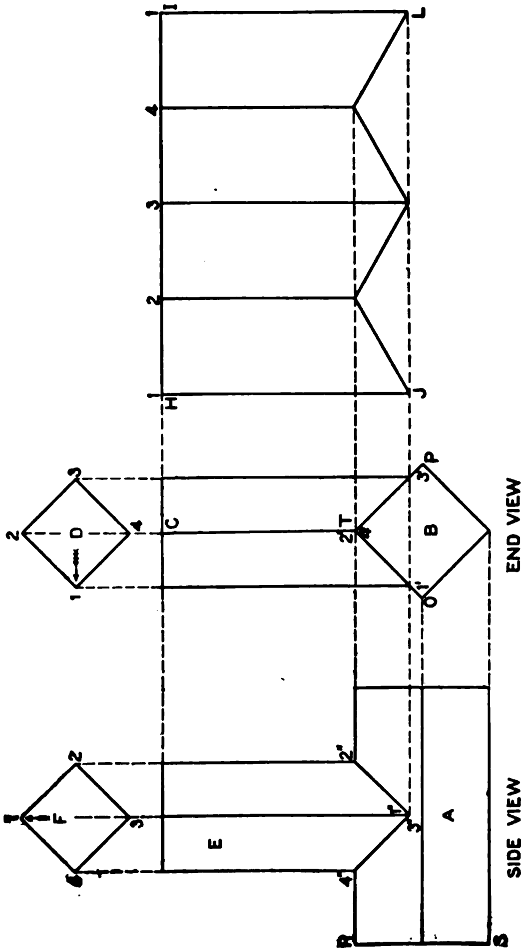



Fig. 10.

tersections 4″, 3″, 1″ and 2″, and place them in Fig. 11 on lines having similar numbers, measuring from the line $O^v P^v$, thus resulting in the intersections 1°, 2°, 3° and 4°. Connecting these points by lines as shown, then $O^vUTP^v$ will be the half development of the top of the horizontal prism. The bottom half will he similar without the opening.

Having described the principles relating to parallel forms, the next subject will be the principles relating to tapering forms. These forms include only the solid figures that have for a base the circle, or any of the regular polygons, also figures of unequal sides which can be inscribed in a circle, the lines drawn from the corners of which terminate in an apex, directly over the center of the base. The forms with which the tinsmith has to deal are more frequently frustums of these figures, and the method used in developing these surfaces is simply to develop the surface of the entire cone or pyramid, and then by simple measurements cut off part of the figure, leaving the desired frustum. Thus in the well-known forms of the dipper, coffee pot, colander, strainer, wash bowl, bucket, funnel, measure, pan, etc., we have the frustums of cones above referred to. In speaking here of metal plate articles as portions of cones, it must be remembered that all patterns are of surfaces, and as we are dealing with tinplate, these patterns when formed are not solids, but merely shells. In works upon Solid Geometry the right cone is defined as a solid with a circular base, generated by the revolution of a right-angle triangle about its vertical side called the axis.

This is more clearly shown in Fig. 12, in which is shown a right cone, which contains the principles applicable to all frustums of pyramids and cones. ABC represents the elevation of the cone; the horizontal section on the line BC being shown by GDEF, which is spaced into a number of equal parts, as shown by the small figures 1 to 12. As the center or apex of the cone is directly over the center *a* of the circle, then the length of each of the lines drawn from the small figures 1 to 12 to the center *a* will be equal both in plan and elevation. Therefore to obtain the envelope or development, use AB or AC as radius, and with A in Fig. 13 as center, describe the arc 1 – 1′. From 1 draw a line to A and starting from the point 1, set off on the arc 1 – 1′ the stretchout or number of spaces contained in the circle DEFG in Fig. 12, as shown by similar figures in Fig. 13. From 1′ draw a line to A. Then A-1-7-1′ will be the development of the right cone of Fig. 12.

Suppose that a frustum of the cone is desired as shown by HICB, Fig. 12; then the opening at the top will be equal to the small circle in plan, and the radius for the pattern will be equal to AI. Now using A in Fig. 13 as a center with AI as radius, describe the arc HI, intersecting the lines 1A and A1′ at H and I respectively. Then H-I-1′-7-1 will be the development for the frustum of the cone.

When a right cone is cut by a plane passed other than parallel to its base, the method of development is somewhat different. This

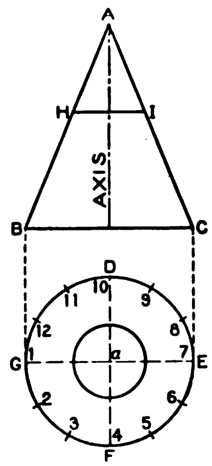


Fig. 12.

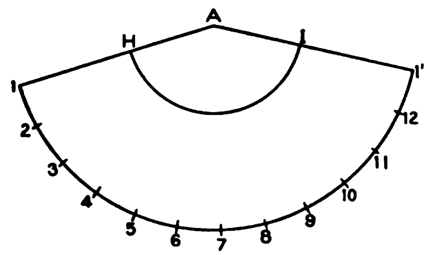


Fig. 13.

is explained in connection with Fig. 14, in which A is the right cone, intersected by the plane represented by the line DE. B represents the plan of the base of the cone, whose circumference is divided into equal spaces. As the intersection of both halves of the cone are symmetrical, it will be necessary to divide only half of plan B as shown by the small figures 1 to 7. From these points, erect lines parallel to the axis of the cone, intersecting the base line of the cone. From these points draw lines to apex F, intersecting the line DE as shown. From the intersections thus obtained on the line DE and at right angles to the axis, draw lines as shown, intersecting the side of the cone FE. Now using F as center and FH as a radius, describe the arc 7-7′. From 7 draw a line to F, and starting from the point 7 set off on the arc 7 – 7′, the stretchout of the circle B as shown by the small figures 7 – 1 – 7′. From these points draw radial lines to the center point F, and intersect them by arcs struck from the center F, with radii equal to similarly numbered intersections on the side FH, and partly shown by points $7^v$– $1^v$– 7°. Trace a line through the points of intersections thus obtained; then 7° – $7^v$ – 7 – 7′ will be the desired development.

These same principles are applicable no matter at what angle the cone is intersected. For the section on the line DE, see the explanation in Mechanical Drawing Part III.

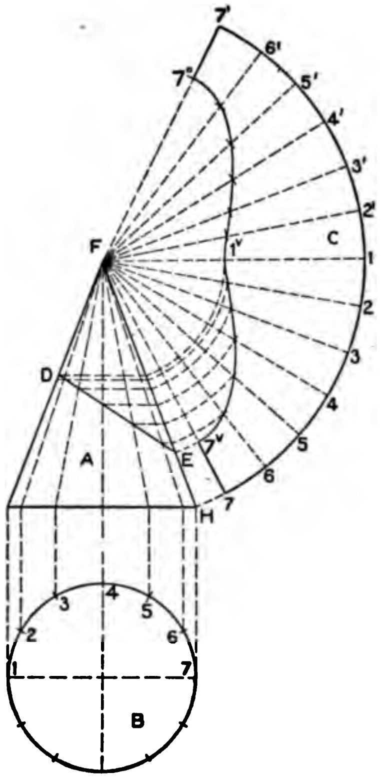


Fig. 14.

Fig. 15 shows the principles applicable to the developments of pyramids having a base of any shape. In this case, we have a square pyramid, intersected by the line DE. First draw the elevation of the pyramid as shown by ABC and in its proper position the plan view as shown by 1, 2, 3, 4. Draw the two diagonal lines 1 – 3 and 2 – 4 intersecting each other at A′. The length of the line AC represents the true length on A′*e*, but is not the correct radius with which to strike the development.

A true length must be obtained on the line A′4 as follows: At right angles to 3 – 4 from the center A′ draw the line A′E′ and using A′ as center and A′4 as radius, describe the arc 4E′ intersecting A′E′ at E′. From E′ erect the perpendicular line E′$1^v$ intersecting the base line BC extended at $1^v$. From $1^v$ draw a straight line to A, which will be the true length on A′4 and the radius with which to strike the development. (See also Part III, Mechanical Drawing) Now with A as center and A–$1^v$ as radius, describe the arc $1^v$–$3^v$–$1^v$. Starting from $1^v$ set off the stretchout of 1 – 2 – 3 – 4 – 1 in plan, as shown by $1^v$–$2^v$–$3^v$–$4^v$–$1^v$ on the arc $1^v$ – $1^v$ ($1^v$ – $2^v$ being equal to 1 – 2, etc.), and from these points draw lines to the apex A and connect points by straight lines as shown from $1^v$ to $2^v$, $2^v$ to $3^v$, $3^v$ to $4^v$ and $4^v$ to $1^v$. Then A$1^v$ $3^v$ $1^v$ will be the development of the square pyramid.

To obtain the cut, in the development of the intersected plane

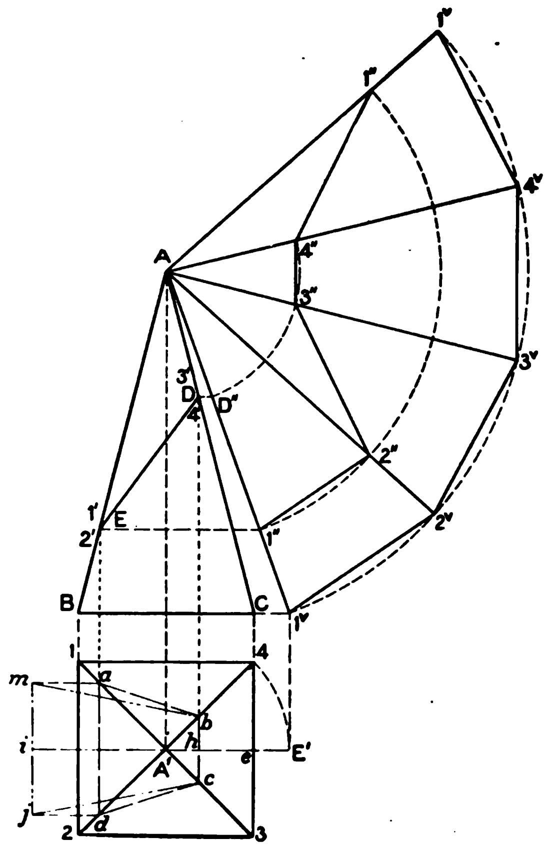



Fig. 15.

DE, which represents respectively the points $3^1$ – $4^1$ and $1^1$ – $2^1$, draw at right angles to the center line, the lines D – D″ and E–1″, intersecting the true length A$1^v$ at D″ and 1″. Using A as center and radii equal to A – D″ and A – 1″ intersect similarly numbered radial lines in the development. Connect these points as shown from 1″ to 2″, 2″ to 3″, 3″ to 4″ and 4″ to 1″. Then $1'' - 1^v - 3^v - 1^v - 1'' - 3''$ will be the development of the intersected square pyramid.

To draw DE in plan drop perpendiculars from D and E intersecting the diagonal lines in plan at *b c* and *d a*. Connect lines as shown at *a*, *b*, *c* and *d*. To obtain the true section of the plane DE, take the length of DE and place it, as shown in plan from *h* to *i*; through *i* draw the vertical line *jm* which is intersected by horizontal lines drawn from points *a* and *d*. Draw a line from *b* to *m* and *c* to *j* which will be the desired section.

These problems just described should be thoroughly studied and practiced on paper, until every step is well understood.

**Practical Workshop Problems** will now be considered, and the student who thoroughly understands the principles explained in the foregoing problems, will be able to develop the patterns with greater ease and in less time than is required by the student, who pays little attention to the principles, but simply proceeds to develop the patterns by blindly following directions. A thorough knowledge of the principles renders the student independent as far as pattern problems are concerned, as he can apply them to new work.

**Short Rules.** There are various short rules, which, while not geometrically accurate, are sufficiently so for all practical purposes and will be introduced as we proceed. In developing patterns for any given article, the problem should be gone over carefully, locating the joints or seams, so that it can be seen, we might say in our minds' eye; by doing this a shorter rule may be employed, thus saving time and expense. The student who pays attention to these smaller details will succeed as a pattern draftsman.

**Allowance for Seaming and Wiring.** As we are dealing with tin plate only, we assume this to have no thickness, and therefore make no allowance for the shrinkage of the metal, when bending in the machine folder or brake.

The amount of the material to be added to the pattern for wiring will vary according to the thickness of the metal. A safe and practical plan is to use a small strip of thin metal about ¼ inch wide and curl this around the wire which is to be used as shown in Fig. 16. This will give the true amount of material required, whether the wire is to be laid in by hand or by means of the wiring machine. First bend off with plyers a sharp corner as shown at *a*, place the wire in the corner and turn A snugly around the wire as shown at B. The amount of A, or the allowance to be added to the height of the pattern is thus obtained. The vertical joint in tinware is usually a lock seam as shown in Fig. 17. Three times the width of the lock *a* must be added to the pattern. In other words, the end *b* has a single edge as *d*, while the other end *c* has a double edge as shown at *a* and *e*; the two ends of the body joining at *f*.

In allowing these edges for the pattern, some workmen prefer to add a single edge on one side of the pattern, and a double edge on the other, while others prefer to allow one-half of the amount required on either side of the pattern. Where the bottom of any piece of tinware is to be joined to the body, it is generally double

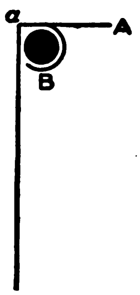



Fig. 16.

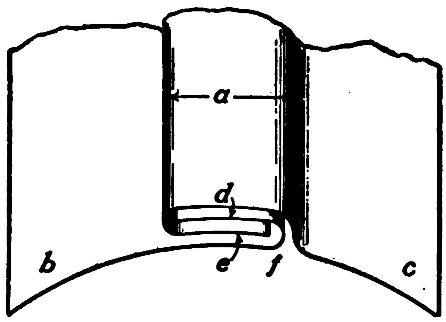



Fig. 17.

seamed as is shown in Fig. 18, where the two operations are clearly shown by A and B whether the seaming is done by hand or machine, while the lock seam in Fig. 17, is done on the groover.

**Notching the Patterns.** Another important point is the notching of the edges of the patterns for seaming and wiring; special attention should be given to this. The notches should be made in such a manner that when the article is rolled up and the wire encased or the seams grooved, the ends of the wire or seam allowance will fit snugly together and make a neat appearance. When an article is made and the notches have not been cut properly, the wire, or uneven lines, will show at the ends of the seam. Fig. 19 shows how the allowance for wire or locks should be cut. A shows the pattern to which an allowance has been made for wire at B and for seaming to the bottom at C. In this case a single edge D has been allowed at one end of the pattern and a double edge of the other as shown at E. Then, using this method of allowance for seaming, notch the allowance for wire B and seam C on a line drawn through the solid lines in the pattern as shown by *aa* and *bb*. The notches of the allowance D and E should be cut at a small angle, as shown.

**Transferring Patterns.** After the pattern has been developed on manilla paper, which is generally used in the shop, it is placed on the tin plate and a few weights laid on top of the paper; then with a sharp scratch awl or prick punch and hammer, slight prick-punch marks are made, larger dots indicating a bend. The paper is then removed and lines scribed on the plate, using the scratch awl for marking the straight lines, and a lead pencil for the curved lines. After laps are added as required, it is ready to be cut out with the shears.

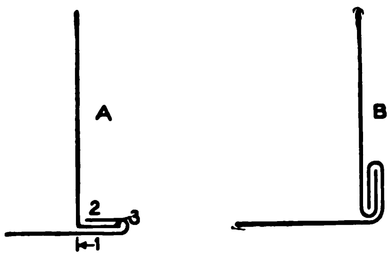


Fig. 18.

## PRACTICAL PROBLEMS.

In presenting the twelve problems which follow, particular attention has been given to those problems which arise in shop practice. These problems should be practiced on cheap manilla paper, scaling them to the most convenient size, and then proving them by cutting the patterns from thin card board, and bending or forming up the models. This will prove both instructive and interesting.

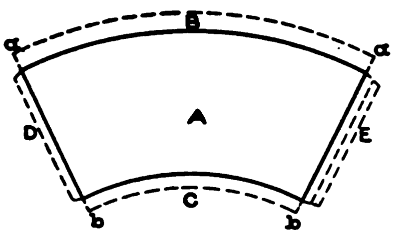


Fig. 19.

**Pail.** The first piece of tinware for which the pattern will be developed is that known as the flaring bucket, or pail, shown in Fig. 20. First draw the center line AB, Fig. 21, upon which place the height of the pail, as shown by CD. On either side of the center line place the half diameters CE of the top and DF of the bottom. Then EFFE will be the elevation of the pail. Extend the lines EF until they meet the center line at B, which will be the center point with which to describe the pattern. Now. with C as center and CE as radius, describe the semi-circle EAE, and divide it into equal spaces, as shown. This semi-circle will represent the half section of the top of the pail.

Fig. 20.

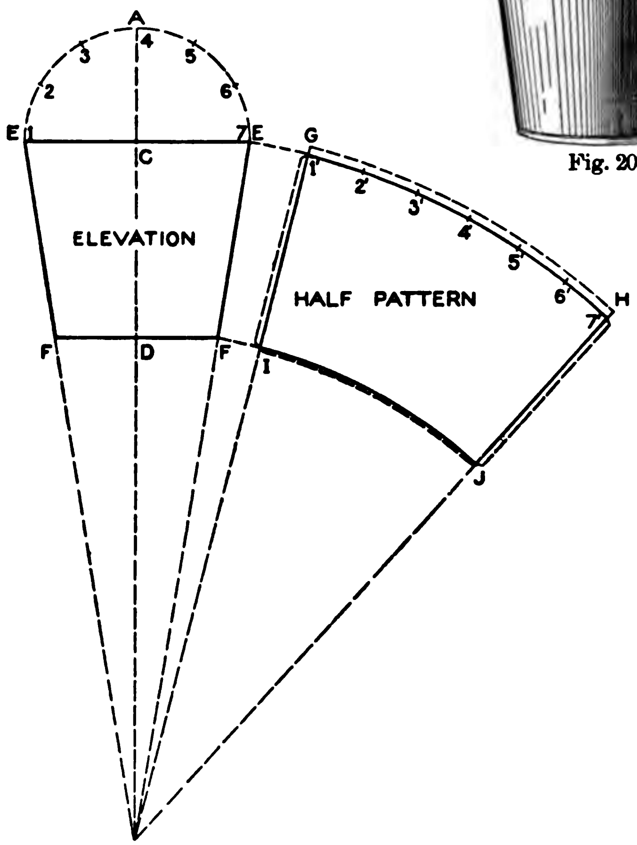



Fig. 21.

For the pattern proceed as follows: With B as center and radii equal to BF and BE, describe the arcs GH and IJ. Draw a line from G to B. Starting from the point G lay off on the arc GH, the stretchout of the semi-circle EAE, as shown by similar figures on GH. From H draw a line to B, intersecting the arc IJ at J. Then GHJI will be the half pattern for the pail, to which laps must be added for seaming and wiring as shown by the dotted lines.

**Funnel and Spout.** In Fig. 22 is shown a funnel and spout, which is nothing more than two frustums of cones joined together.

Fig. 23 shows how the patterns are developed. In this figure the full elevation is drawn, but in practice it is necessary to draw only one-half of the elevation, as shown on either side of the center

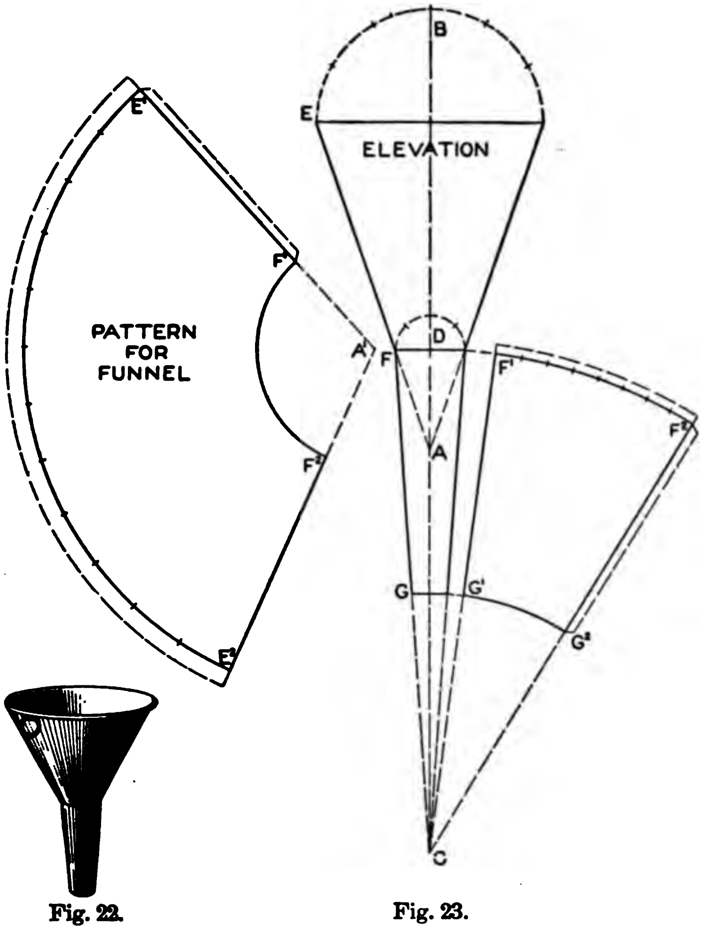



Fig. 22. Fig. 23.

line BC. Extend the contour lines until they intersect the center line at C and A. Now, using A' as a center, with radii equal to AF and AE, describe the arcs F'F² and E'E² respectively. On the arc E'E² lay off twice the number of spaces contained in the semi-circle B, then draw radial lines from E' and E² to A', intersecting the inner arc at F'F², which completes the outline for the pattern. Laps must be allowed for wiring and seaming. For the pattern for the spout use C as a center, and with radii equal to CG and CF describe the arcs $F^1F^2$ and $G^1G^2$. On $F^1F^2$ lay off twice the amount of spaces contained in the semi-circle D, and draw radial lines from $F^1$ and $F^2$ to C. Then $F^1F^2G^1G^2$ will be the pattern for the spout. The dotted lines show the edges allowed.

**Hand Scoop.** In Fig. 24 is shown a perspective view of a hand scoop, in the development of which the parallel and radial line developments are employed. Thus A and B represent intersected cylinders, while C represents an intersected right cone. The method of obtaining the patterns for the hand scoop is clearly shown in Fig. 25; these principles are applicable to any form of hand scoop.

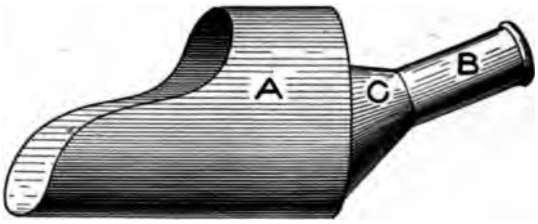


Fig. 24.

First draw the side view of the scoop as shown, in line with which place the half section; divide this into a number of equal spaces as shown by the figures 1 to 7. From these points draw horizontal lines intersecting the curve of the scoop. In line with the back of the scoop draw the vertical line 1–1′, upon which place the stretchout of twice the number of spaces contained in the half section, as shown by similar numbers on the stretchout line. From these points on the stretchout line draw horizontal lines, which intersect lines drawn from similarly numbered points on the curve of the scoop parallel to the stretchout line. Trace a line through points thus obtained, which will give the outline for the pattern for the scoop, to which edges must be allowed as shown by the dotted line. The pattern for the back of the scoop is simply a flat disc of the required diameter, to which edges for seaming are allowed.

When drawing the handle, first locate the point at which the center line of the handle is to intersect the back of the scoop, as at $2^{\circ}$. Through this point, at its proper or required angle, draw the center line $2^{\circ}2^{x}$. Establish the length of the handle, and with any [illegible] center line as center, draw the section

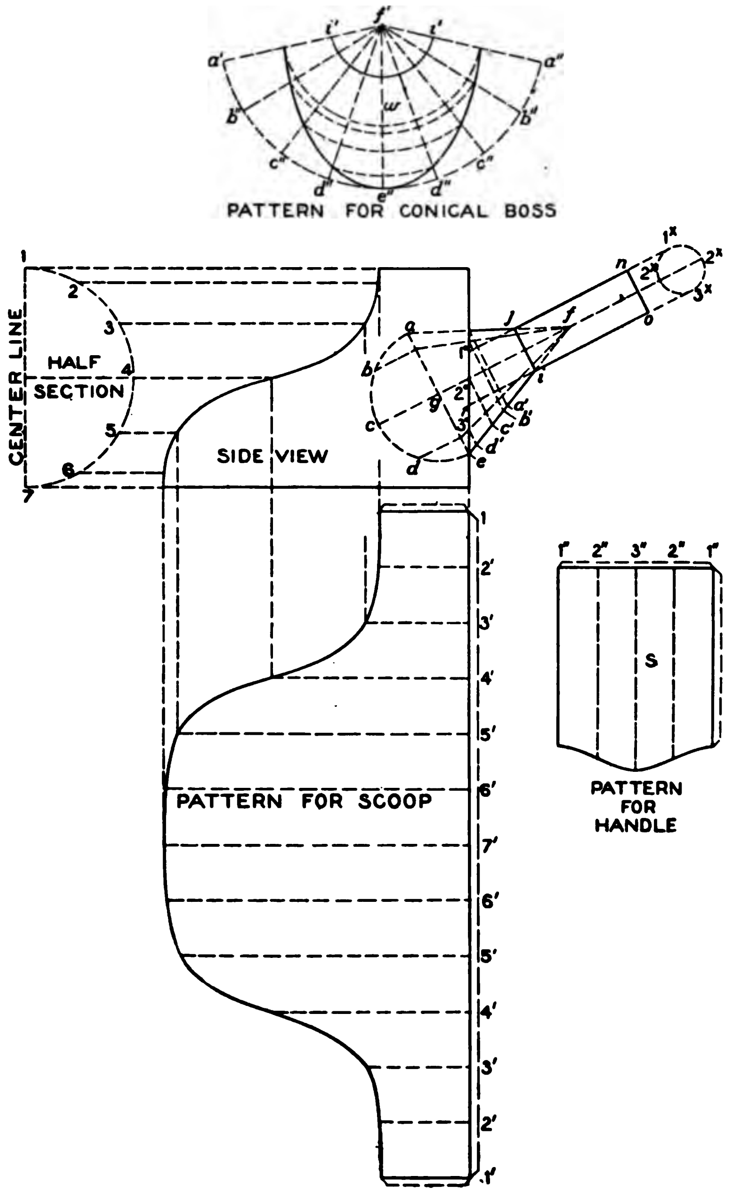

PATTERN FOR CONICAL BOSS
CENTER LINE
HALF SECTION
SIDE VIEW
PATTERN FOR SCOOP
PATTERN FOR HANDLE
S

Fig. 25.

as shown by $1^x$, $2^x$ $3^x$, and $2^x$, and divide the circumference into equal spaces, in this case four. (In practical work it would be better to use more than four). Parallel to the center line and from these four divisions draw lines as shown intersecting the back of the scoop at 1°, 2° and 3°. For the pattern draw any horizontal line in S, as 1″3″1″, upon which place the stretchout of the section of the handle as shown by 1″ 2″ 3″ 2″ 1″ on the stretchout line. From these points at right angles to the line of the stretchout, draw lines as shown. Take the various distances measuring from the line *no* in side view to points 1°, 2° and 3°, and place them on lines drawn from similar numbers in S, measuring from the line 1″3″1″. A line traced through these points of intersection will be the pattern for the handle, laps being indicated by dotted lines. To close the top of the handle *no*, a small raised metal button is usually employed, which is double-seamed to the handle.

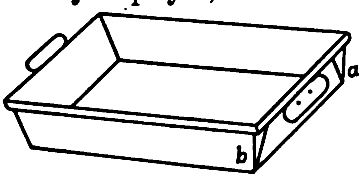



Fig. 26.

To draw the conical boss in side view, first locate the points *i* and *e*, through which draw a line intersecting the center line of the handle at *f*. At right angles to the center line, draw the line *ij* representing the top opening of the boss. In similar manner, at right angles to the center line, draw a line from *e* as shown by *ea*, intersecting the center line at *g*. Now make *ga* equal to *ge* and draw a line from *a* to the center *f*, which will intersect the back of the scoop as shown and the top of the boss at *j*. With *g* as center and *ga* as radius describe the half section of the cone, divide this into equal spaces as shown by *abcde*, from which draw lines at right angles to and intersecting the base of the cone *ae* as shown. From the intersections on the base line draw radial lines to the apex *f*, intersecting the back of the scoop as shown. From these intersections at right angles to the center line, draw lines intersecting the side of the boss at *a′b′c′d′*. For the pattern proceed as shown in diagram *w*. With radius equal to *fe* in the side view and *f′* in *w*, as a center describe the arc *a′a″*. Draw a line from *a″* to the center *f′*, and starting from *a″* set off on the arc *a′a″* twice the number of spaces contained in the semi circle *ace* in side view, as shown by similar letters in diagram *w*. From these points draw radial lines to the center *f*. Now using *f* in *w* as a center describe the arc *i'i'*. In similar manner, using as radii *fa'*, *fb'*, *fc'*, *fd'* and *fe* in side view, and *f* in *w* as center, describe arcs intersecting radial lines having similar letters as shown. A line traced through points thus obtained forms the pattern for the conical boss.

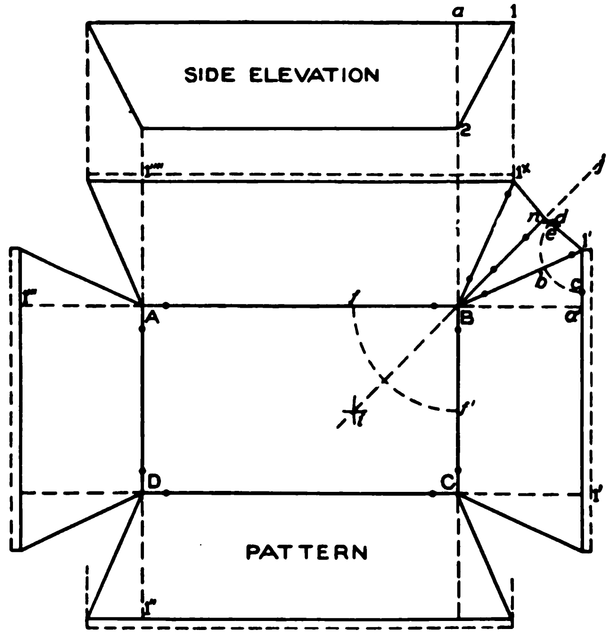



Fig. 27.

**Drip Pan.** Fig. 26 shows a view of a drip pan with beveled sides. The special feature of this pan is that the corners *a* and *b* are folded to give the required bevel and at the same time have the folded metal come directly under the wired edge of the pan. A pan folded in this way gives a water tight joint without any soldering. Fig. 27 shows the method of obtaining the pattern when the four sides of the pan have the same bevel. First draw the side elevation having a bevel indicated at *a*21. Now draw ABCD, a rectangle representing the bottom of the pan. Take the distance of the slant 1 – 2 in elevation and add it to each side of the rectangular bottom as shown by 1', 1'', 1''' and 1''''. Through these points draw lines parallel to the sides of the bottom as shown. Now extend the lines of the bottom AB, BC, CD and DA intersecting the lines just drawn. Take the projection of the bevel *a* to 1 in side elevation and place it on each corner of the pan, as, for example, from *a'* to 1'. Draw a line from 1' to B. By proceeding in this manner for all the corners, we will have the butt miters, if the corners were to be soldered raw edge. Where the bevels are equal on all four sides, the angle $1^x$B1' is bisected as

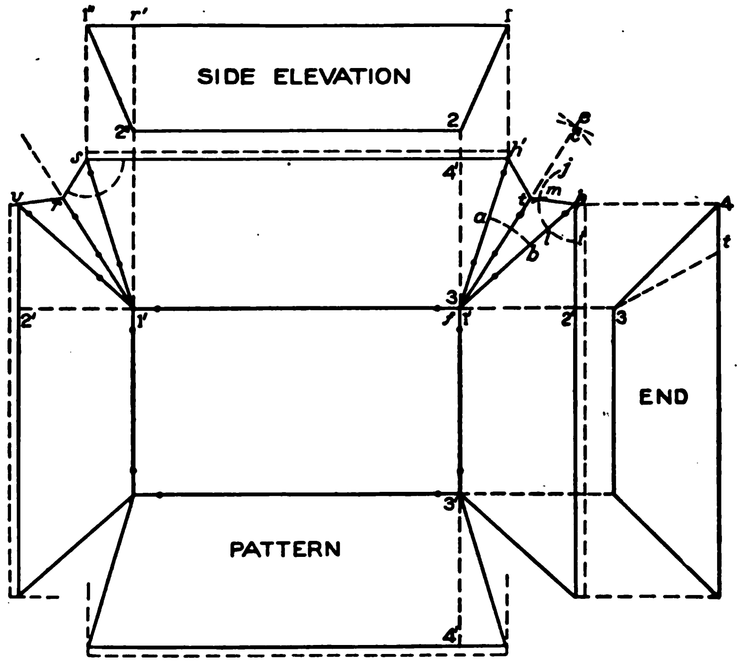



Fig. 28.

follows: With B as center and any radius draw the arc $ff^x$ intersecting the sides of the bottom as shown. Then with a radius greater than one half of $ff^x$, with $f$ and $f^x$ respectively as centers, draw arcs which intersect each other at *i*. Draw a line through the intersection *i* and corner B, extending it outward toward *j*.

Now with 1' as center, and radius less than one-half of $1'-1^x$, draw arc *d–c*, intersecting the line 1' B at *b*, and intersecting the line 1'*a'* at *c*. Then with *b* as center and *bc* as radius, intersect the arc *cd* at *e*. Draw a line from 1' to *e*, intersecting the line *ij* at *n*. From *n* draw a line to $1^x$. Transfer this cut to each of the corners, which will complete the pattern desired. Dotted lines indicate the wire allowance.

Sometimes a drip pan is required whose ends have a different flare from those of the sides, and in one case the folded corners are to be bent toward the end, while it may be required that the corners be folded towards the side. The principles are similar in both cases, but as the method of applying these principles may be a little difficult, Fig. 28 has been prepared, which will explain the application of these principles.

First draw the side elevation, showing the desired flare; also draw the end elevation, which shows the flare of the sides, being careful that the vertical heights in both views are the same. Now draw the pattern of the pan as follows: Take the distance 1–2 in side elevation and place it on the ends of the bottom as shown on either side by 1′–2′. Similarly take the distance 3–4 in end elevation and place it on the sides of the bottom as shown on either side by 3′–4′. Through the point 2′ and 4′ draw lines parallel to the ends and sides of the bottom as shown, which intersect lines dropped from the end and side views respectively. *hfh′* represent the butt miters which should be placed on all corners. If these miters have been correctly developed, the lengths from *h* to *f* must be equal to *fh′*. Bisect the angle *hfh′* by using *f* as center and drawing the arc *ab*, then use *a* and *b* as centers and obtain the intersection *c*, through which draw the line *ef*. Now assume that the folded corner is to be turned towards the end view as shown by *t*3. Using *h* as a center draw the arc *ij*. Then with *l* as center and *li* as radius, intersect the arc *ij* at *m*. Draw a line from *h* through *m*, meeting the line *ef* at *t*, and draw a line from *t* to *h′*.

If the folded corner were turned towards the side as shown by *r′*–2″ in the side view, bisect the angle *v*1′*s* as before, and use *s* as a center and proceed as already explained. Note the difference in the two corners. The only point to bear in mind is, that when the corner is to be folded towards the end, transfer the angle of the end miter; while if the corner is to be turned towards the side, transfer the angle of the side miter. If the corners were to be folded toward the ends of the pan, the cut shown in the right-hand corner would be used on all four corners, while if the corners were to be folded towards the sides, the cut shown on the left-hand corner would be used.

**Tea Pot.** In Fig. 29 is shown the well-known form of the tea or coffee pot, for which a short method of developing the pattern is shown in Fig. 30. This is one of the many cases where a short rule can be used to advantage over the geometrical method. While it is often advisable to use the true geometrical rule, the difference between that and the method here shown is hardly noticeable in practice. Of course, if the body A and spout B were larger than the ordinary tea pots in use, it would be necessary to use the true geometrical rule, which is thoroughly explained for Plates I, II and III.

Fig. 29.

The pattern for the body of the tea pot will not be shown, only the short rule for obtaining the opening in the body to admit the joining of the spout. The method of obtaining the pattern for the body is similar to the flaring vessels shown in previous problems.

First draw the elevation of the body of the tea pot as shown at A. Assume the point *a* on the body and draw the center line of the spout at its proper angle as shown by 2*b*. Establish the point 3 of the bottom of the spout against the body, also the point $3^x$ at the top and draw a line from 3 through $3^x$ intersecting the center line at *b*. At right angles to the center line and from 3 draw the line 3 – 1 and make *c*1 equal to *c*3. From 1 draw a line to the center point and from $3^x$ draw a horizontal line until it intersects the opposite side of the spout at $1''$. Then $1' - 1'' - 3^x - 3$ will be the side view of the spout. Now with *c* as a center draw the half section 1–2–3 and divide it into equal spaces; in this case but two (in practical work more spaces should be employed). From these points and at right angles to 1 – 3 draw lines intersecting the base of the spout as shown, and draw lines from these points to the center *b*. Thus line 1*b* intersects the body at $1'$ and the top of the spout at $1''$; line 2*b* intersects the body at *a* and the top of the spout as shown, while line 3*b* cuts at 3 and the top of spout at $3^x$. From these intersections at right angles to the center line *ab*, draw lines intersecting the side of the spout at 3, $2^\circ$, $1^\circ$ at the bottom and $1^x$, $2^x$, $3^x$ at the top. Now with *b* as center and *b*3 as radius, describe the arc $3'' - 3''$ upon which place the stretchout of twice the number of spaces contained in the half section 1 - 2 - 3, as shown by similar figures on 3″ - 3″; from these points draw radial lines to the center *b*, and intersect them by arcs drawn with *b* as a center and radii equal to the intersections contained on the side of

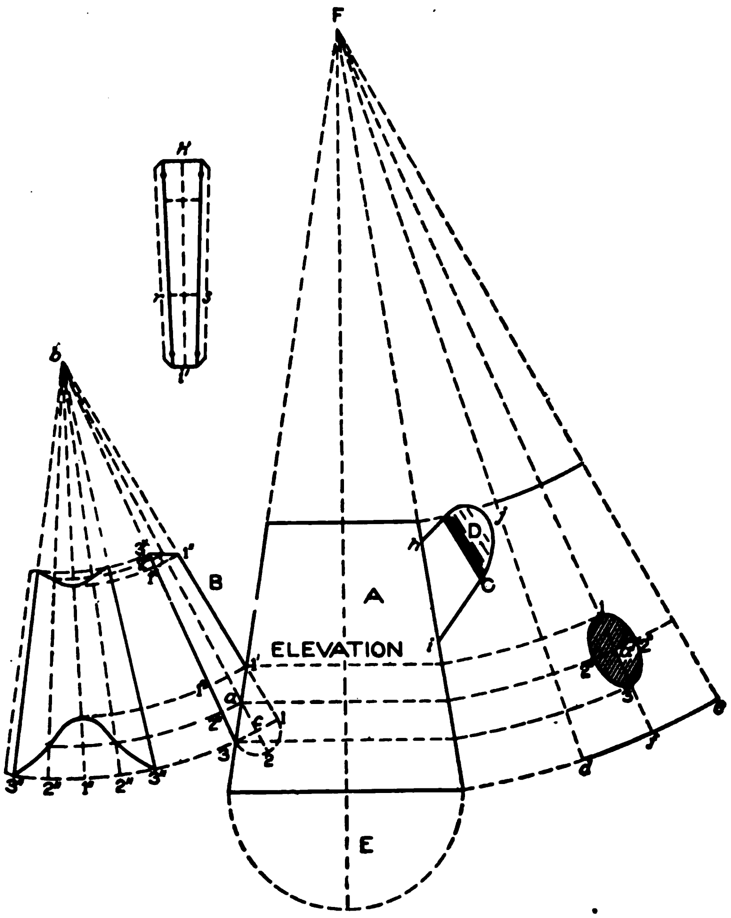



Fig. 30.

the spout 3 - 3ˣ. To form the pattern, trace a line through points thus obtained and make the necessary allowance for edges.

It should be understood that in thus developing the spout, the fact that the spout intersects a round surface has not been considered; it was assumed to intersect a plane surface. As already stated the difference in the pattern is so slight that it will not be noticeable in practice. Had we developed the pattern according to the true geometrical rule, it would present a problem of two cones of unequal diameter intersecting each other, at other than at right angles to the axes.

For the pattern for the opening in the body, draw lines at right angles to the center line of the body from intersections 1′, *a* and 3 intersecting the opposite side of the body as shown. With F as a center draw a partial pattern of the body as shown by *de*. From any point *f* draw a line to the center F. Now with F as center draw the arcs 1, 2° and 3. The distance 1 to 3 on the line F*f* represents the length of the opening, while a line drawn through *a* at right angles to the center line *bc* of the spout represents the width of the opening. Therefore take the distance from *a* to 2° and place it as shown from *a*′ on the line *f*F to 2° – 2° on either side on the arc. Trace an ellipse through 1 – 2° – 3 – 2° for the shape of the opening.

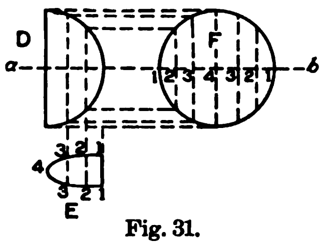


Fig. 31.

The pattern for the handle is obtained by taking the stretchout of *hji* and placing it as shown on the vertical line *h′i′*. At right angles to *h′i′* on either side, at top and bottom add the desired width of the handle and draw the lines shown; add edges for wiring or hem edge.

For the pattern for the grasp D which is placed inside on the handle proceed as is shown in Fig. 31. Let D represent an enlarged view of part of the handle in which the grasp is to be soldered. Directly in line with it draw the section E taking care that the width from 1 to 1 will not be wider than that portion of the handle from *r* to *s* in Fig. 30, being the width at C in the elevation. Divide the section E in Fig. 31 into a number of equal spaces, from which draw vertical lines intersecting the curve D as shown. Draw the center line *ab* upon which lay off the stretchout of E as shown by similar figures. Through these points draw lines which intersect with lines drawn from similar intersections in the curve D parallel to *ab*. Trace a line through the points thus obtained as shown at F.

**Foot Bath.** In Fig. 32 is shown an oval foot bath; the principles used in obtaining the pattern of which are applicable to any form of flaring vessels of which the section is elliptical or struck from more than two centers. In this connection it may be well to explain how to construct an ellipse, so that a set of centers can be obtained with which to strike the arcs desired. Fig. 33 shows the method of drawing an approximate ellipse, if the dimensions are given. Let AB represent the length of the foot bath and CD its width. On BA measure BE equal to CD. Now divide the distance EA into three equal parts as shown by 1 and 2. Take two of these parts as a radius, or E2, and with O as center, describe arcs intersecting the line BA at X and X¹. Then with XX¹ as a radius and using X and X¹ as centers describe arcs intersecting each other at C and D. Draw lines from C to X and X¹ and extend them toward F and G respectively. Similarly from D draw lines through X and X¹, extending them towards I and II respectively. Now with X and X¹ as centers, and XA and X¹B as radii describe arcs intersecting the lines ID, FC, GC and HD at J, K, L and M, respectively. In similar manner

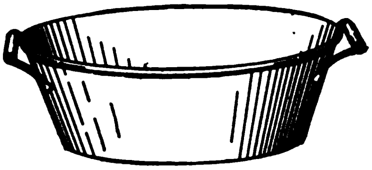


Fig. 32.

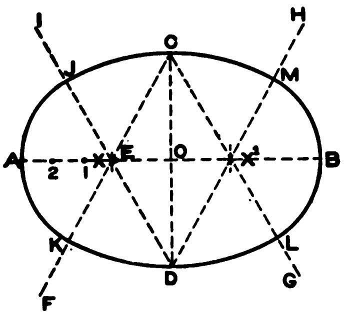



Fig. 33.

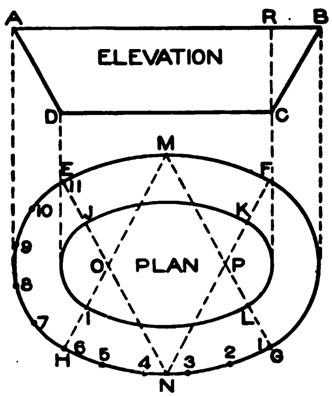



Fig. 34.

with D and C as centers and DC and CD as radii describe arcs which must meet the arcs already drawn at J, M, L and K, respectively, forming an approximate ellipse. In Fig. 34 let ABCD represent the side elevation of the pan, whose vertical height is equal to RC.

In precisely the same manner as described in Fig. 33 draw the plan as shown, in correct relation to the elevation, letting EFGH be the plan of the top of the pan, and JKLI the plan of the bottom, struck from the centers, O,M,P and N. The next step is to obtain the radii with which to strike the pattern. Draw a horizontal line RE in Fig. 35 equal in length to NE in plan in Fig 34. Take the vertical height RC in elevation, and place it as shown by RC in Fig. 35 on a line drawn at right angles to RE. Parallel to RE and from the point C, draw the line CJ equal to NJ in Fig. 34.

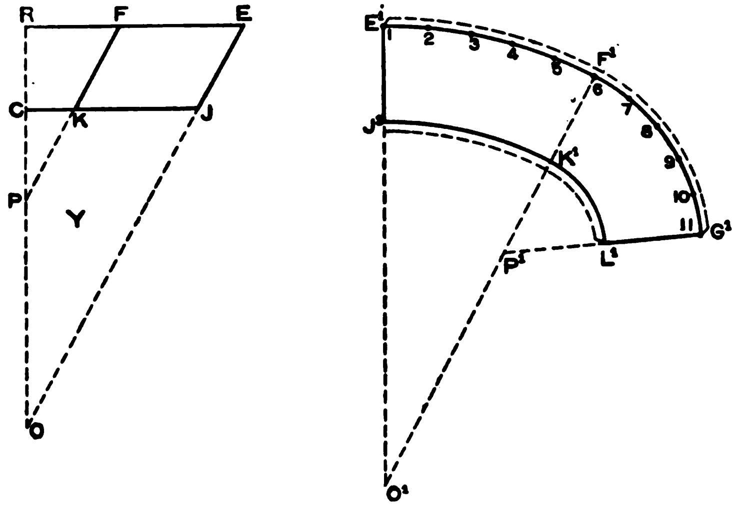



Fig. 35.

Now draw a line from E to J in Fig. 35, extending it until it meets the line RC produced. Then OJ and OE will be the radii with which to make the pattern for that part of the pan or foot bath shown in plan in Fig. 34 by EFKJ and GHIL.

To obtain the radii with which to strike the smaller curves in plan, place distances PF and PK on the lines RE and CJ in Fig. 35 as shown by RF and CK. Draw a line from F through K until it meets the line RO at P. Then PK and PF will be the radii with which to strike the pattern, for that part shown in plan in Fig. 34 by KFGL and IHEJ. Now divide the curve from G to H and H to E (Fig. 34) into a number of equal spaces. To describe the pattern draw any vertical line $E^1O^1$ (Fig. 35) and with $O^1$ as center and radii equal to OJ and OE in the diagram Y, describe the arcs $J^1K^1$ and $E^1F^1$ as shown. On the arc $E^1F^1$ lay off the stretchout of GH in plan in Fig. 34 as shown by similar figures in Fig. 35. From the point 6 on the arc $E^1F^1$ draw a line to $O^1$ intersecting the curve $J^1K^1$. Now, with PF in diagram Y as radius and $F^1$ as a center describe an arc intersecting the line $F^1O^1$ at $P^1$. Then using $P^1$ as a center and with radii equal to $P^1K^1$ and $P^1F^1$ describe the arcs $K^1L^1$ and $F^1G^1$ as shown. On the arc $F^1G^1$ starting from point 6 lay off the stretchout of HE, Fig. 34. From 11 draw a line to $P^1$ intersecting the arc $K^1L^1$ at $L^1$. Then $E^1F^1G^1L^1K^1J^1$ will be the half pattern, the allowance for wiring and seaming being shown by the dotted lines.

Fig. 36.

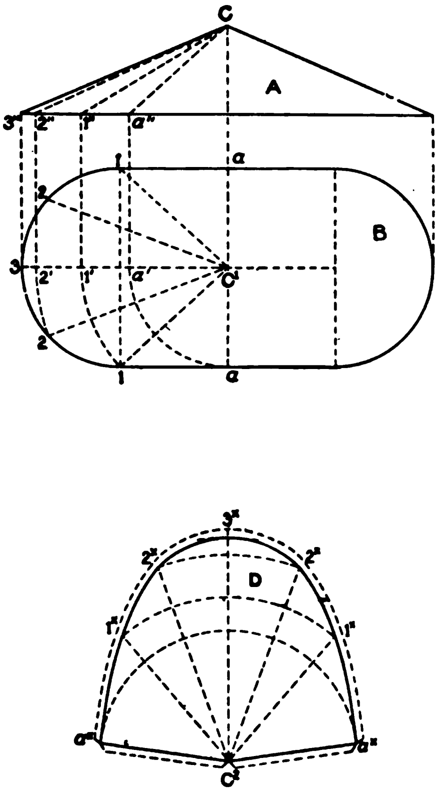



Fig. 37.

Should the article be desired in four sections, two pieces of $F^1K^1L^1G^1$ would be required. The pattern for the bottom of the pan is shown by the inner ellipse in Fig. 34 to which of course edges must be allowed for double seaming.

**Wash Boiler.** In Fig. 36 is shown a perspective view of a wash boiler to which little attention need be given, except to the raised cover. First draw the plan of the cover B, Fig. 37, which shows straight sides with semi-circular ends. In line with the plan draw the elevation A, giving the required rise as at C. Let C represent the apex in elevation, and $C^1$ the apex in plan. As both halves of the cover are symmetrical, the pattern will be developed for one half only. Divide the semi-circle 1 – 3 – 1 into a number of equal spaces as shown by the small figures 1, 2, 3, 2 and 1. From these points draw radial lines to the apex $C^1$, and through $C^1$ draw the perpendicular *aa*. C3″ in elevation represents the true length of $C^13$ in plan, and to obtain the true length of $C^12$, $C^11$ and $C^1a$, it will be necessary to construct a diagram of triangles as follows: With $C^1$ as center, and $C^1a$, $C^11$ and $C^13$ as radii, describe arcs intersecting the center line in plan at *a*′, 1′ and 2′. From these points at right angle to $3C^1$ erect lines intersecting the base line of the elevation at *a*″, 1″, 2″ and 3″, from which draw lines to the apex C, as shown. Now, with radii equal to C3″, C2″, C1″ and C*a*″, and $C^2$ as center describe arcs $3^x$,$2^x2^x$, $1^x1^x$ and $a^xa^x$. From $C^2$ erect the perpendicular intersecting the arc $3^x$ at $3^x$. Now set the dividers equal to the spaces 3 to 2 to 1 to *a* in plan, and starting from $3^x$ step off to similar numbered arcs, thus obtaining the intersections $2^x1^xa^x$; from $a^x$ draw lines to $C^2$, and trace a line $a^x3^xa^x$ to get the half pattern for the cover. Allow edges for seaming.

Fig. 38.

The body of the boiler requires no pattern, as that is simply the required height, by the stretchout of the outline shown in plan. The handles shown on the body and cover in Fig. 36 are plain strips of metal to which wired or hem edges have been allowed.

**Measure.** Fig. 38 shows a flaring-lipped measure with handle attached. Care should be taken in laying out the patterns for these measures, that when the measure is made up it will hold a given quantity. While there are various proportions used in making up the size of the measure, the following table gives good proportions:

| Quantity. | Bottom Diameter in inches. | Top Diameter in inches. | Height. |
|---|---|---|---|
| 1 Gill. | 2.06 | 1.37 | 3.10 |
| ½ Pint. | 2.60 | 1.75 | 3.89 |
| 1 Pint. | 3.27 | 2.18 | 4.90 |
| 1 Quart. | 4.12 | 2.75 | 6.18 |
| ½ Gallon. | 5.18 | 3.45 | 7.78 |
| 1 Gallon. | 6.55 | 4.35 | 9.80 |

Fig. 39 shows the method of laying out the pattern for the measure and lip. First draw the elevation A to the desired size

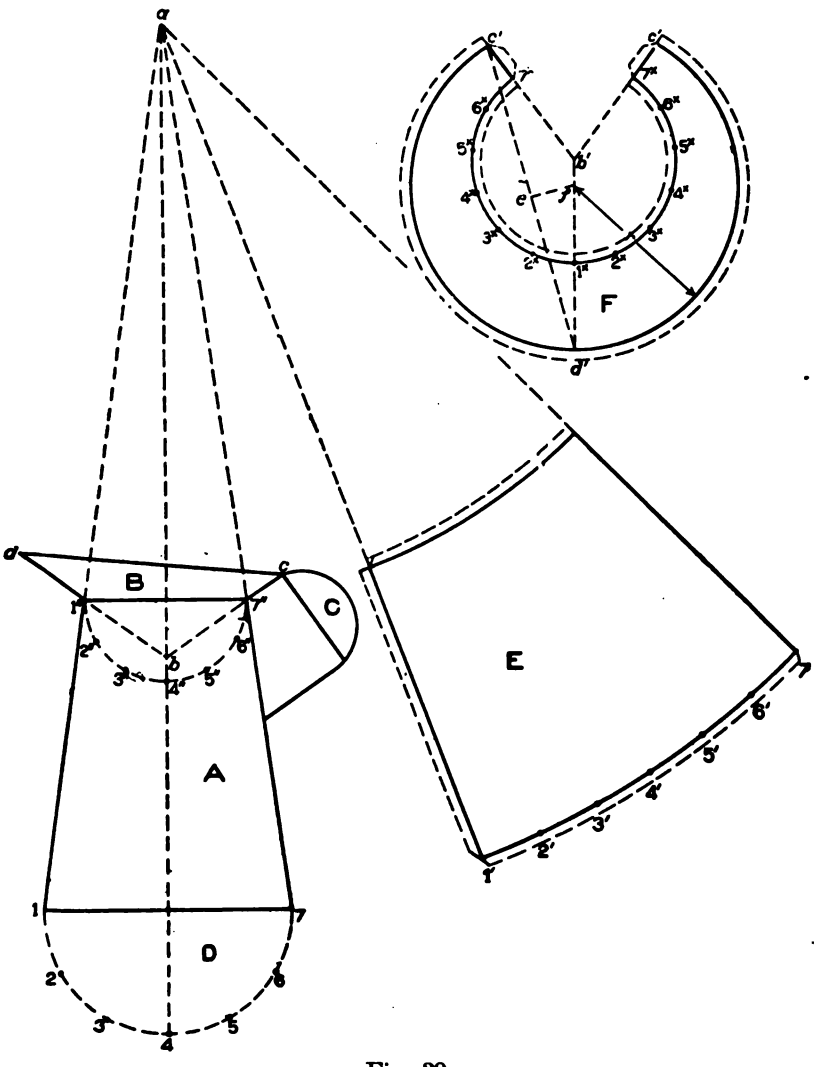



Fig. 39.

and assume the flare of the lip B, as shown by *db*. From *b* draw a line through 7″ to *c* which is a chosen point, and draw a line from *c* to *d*. Draw the handle C of the desired shape. Now extend contour lines of the measure until they intersect at *a*, and draw the half section of the bottom of the measure as shown at D; divide this semi-circle into equal parts as shown. Now, with $a$ as a center, and $a7$ and $a7''$ as radii, describe the arcs as shown. From any point (as $1'$) draw a radial line to $a$, and starting at $1'$ set off the number of spaces contained in the half section D, as shown by the small figures $1'$ to $7'$. From $7'$ draw a radial line to $a$. Allow edges for wiring and seaming. E represents the half pattern for the body of the measure. We find that lip B is simply an intersected frustum of a right cone, which can be developed as shown in the pattern for conical boss of Fig. 25.

There is, however, a shorter method which serves the purpose just as well; this is shown at F, Fig. 39. First draw the half section of the bottom of the lip, which will also be the half section of the top of the measure, as shown by the figures $1''$ to $7''$. Now, with radii equal to $b-1''$, or $b-7''$ and $b'$ in F as center, describe the arc $7^x7^x$. From $b'$ drop a vertical line intersecting the arc at $1^x$. Starting from the point $1^x$, set off the spaces contained in the half section $1''-4''-7''$, as shown by the figures $1^x$ to $7^x$. From $b'$ draw lines through the intersections $7^x7^x$, extending them as shown. Now take the distance from $1''$ to $d$ of the front of the lip and place it as shown by $1^xd'$ in F. In similar manner take the distance from $7''$ to $c$ of the back of the lip and place it as shown in F from $7^x$ to $c'$ on both sides. Draw a line from $c'$ to $d'$, and bisect it to obtain the center $e$. From $e$, at right angles to $c'd'$, draw a line intersecting the line $b'd'$ at $f$. Then using $f$ as center, with radius equal to $fd'$, draw the arc $c'd'c'$, as shown. Adding laps for seaming and wiring will complete the pattern for the lips.

The pattern for the handle and grasp C is obtained as shown in Figs. 30 and 31.

**Scale Scoop.** Fig. 40 shows a scale scoop, wired along the top edges and soldered or seamed in the center. The pattern is made as shown in Fig. 41. First draw the elevation of the scoop as shown by ABCD. (In practice the half elevation, BDC, is all that is necessary.) At right angles to BD and from the point C, draw the indefinite straight line CE, on which a true section is to be drawn. Therefore, at right angles to CE, from points C and E, draw the lines CC and $EE^1$. From $E^1$ erect a perpendicular as $E^1C$, on which at a convenient point locate the center F; with

FE' as radius, describe the arc HE'I. Then HE'I will be the true section on CE in elevation. Divide the section into a number of equal parts as shown by the figures 1 to 7; through these points, parallel to the line of the scale BD, draw lines intersecting BC and CD as shown. At right angles to BD draw the stretchout line 1 - 7 and place upon it the stretch-out of the section as shown by similar figures. At right angles to 1 - 7 draw lines which intersect lines drawn at right angles to BD, from intersections on BC and DC having similar numbers. Trace a line through these

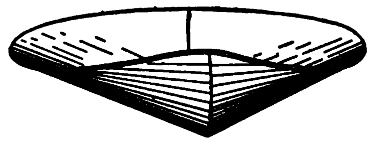


Fig. 40.

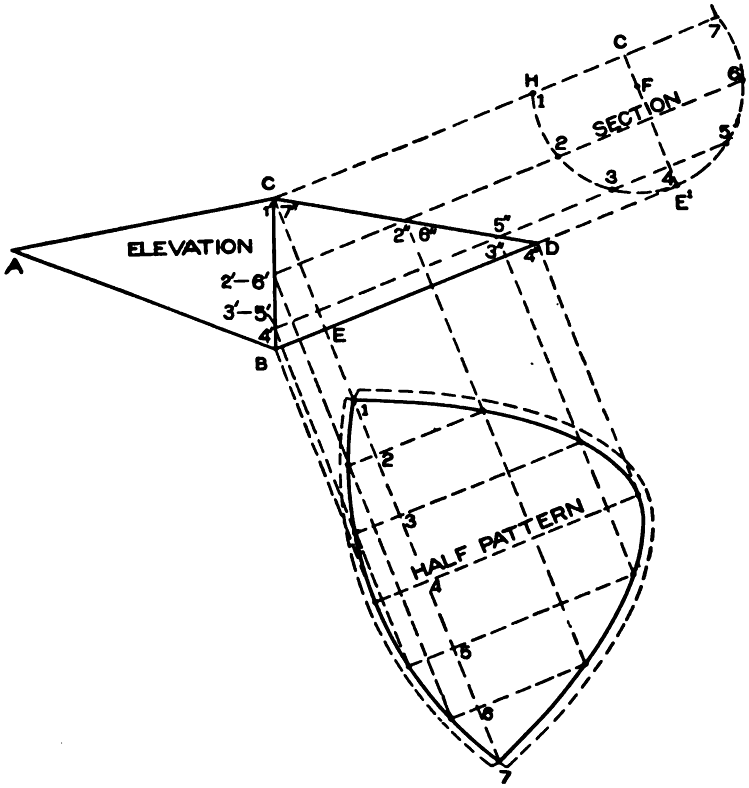



Fig. 41.

points and thus obtain the desired pattern. The dotted outline shows the lap and wire allowance.

In Fig. 42 is shown a perspective view of a **dust pan** with a tapering handle passing through the back of the pan and soldered to the bottom. The first step is to draw the plan and elevation which is shown in Fig. 43. Let ABC be the side view of the pan. Directly below it, in its proper position, draw the bottom DEFG. From the point C in elevation draw a line *d'd* indefinitely. Now bisect the angle EFG. Through *c* and F draw the line *cd*, intersecting the line *dd'* at *d*. From *d* draw a line to G.

In the same manner obtain E*d'*D on the opposite side, which

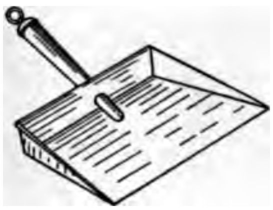


Fig. 42.

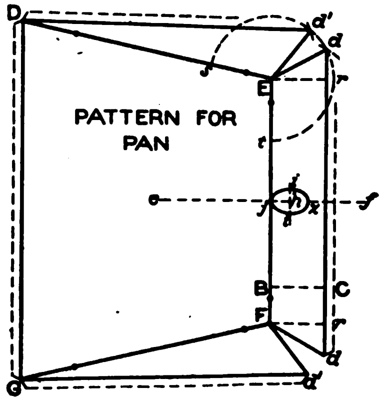



Fig. 44.

will complete the plan view of the pan. Now locate the point *h* in side view, through which the center line of the handle shall pass, and draw the line *lm* Through *m*, the end of the handle, draw the line *no* at right angles to *lm*, and assume *o* the half width at the top and *j* the point where the contour line of the handle shall meet the back of the pan, and draw a line from *o* through *j*, intersecting the center line *lm* at *l*. Make *mn* equal to *mo* and draw a line from *n* to *l*, intersecting the back of the pan at *x*. Through *h* at right angles to the center line draw *ij''*, giving the diameter of the handle at that point to be used later. This completes the elevation of the handle; the plan view is shown by dotted lines and similar letters, but is not required in developing the pattern.

For the pattern of the pan proceed as is shown in Fig. 44, in which DEFG is a reproduction of similar letters of Fig. 43. Take the distance of BC in side view, Fig. 43, and place it as shown by

BC in Fig. 44 and through C draw a line parallel to EF as shown. At right angles to and from EF draw E*r* and F*r*, then take the distance from *r* to *d* in plan in Fig. 43 and place it as shown from *r* to *d* on both sides in Fig. 44. Draw the lines *d*F and *d*E. Now using E as center, and radius equal to E*d* describe the arc *st*. Then with *td* as radius and *s* as center, intersect the arc *st* at *d'*. Draw a line from *d'* to D. In similar manner obtain *d'*G on the opposite side, which will complete the pattern for the pan. Allow laps for wiring and edging.

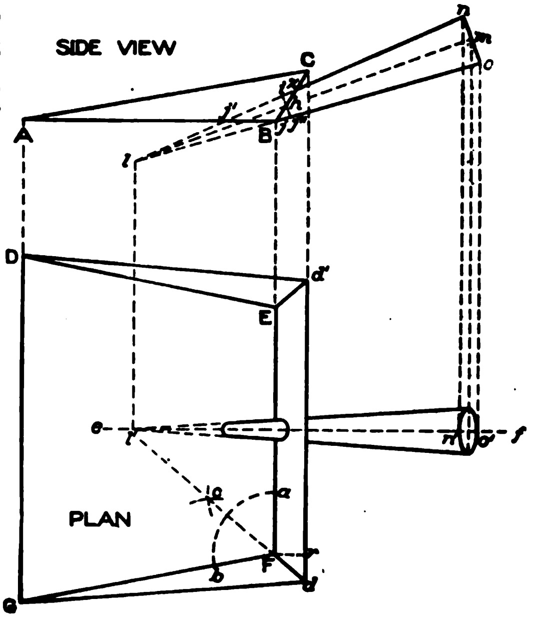



Fig. 43.

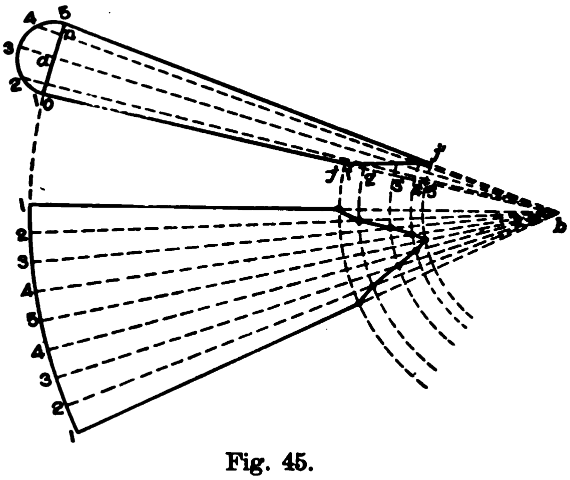


Fig. 45.

The opening in the back of the pan to allow the handle to pass through is obtained by first drawing a center line *ef*, then take the distances from *j* to *h* and *h* to *x* in Fig 43, noting that *j* comes directly on the bend B, and place it in Fig. 44 on the line *ef* from *j* to *h* to *x*, placing *j* on the bend as shown. Now take the distance from *h* to *i* or *h* to *j''* in side view in Fig. 43 and place it in Fig. 44 from *h* to *i* on either side; on a line drawn through the points *jixi* draw an ellipse shown. Fig. 45 shows the method of drawing the pattern for the tapering handle. From the figure we find that we have a frustum of a right cone. To illustrate each step the handle has been slightly enlarged. *n*, *o*, *j*, *j'* represents *n*, *o*, *j*, *j'* in Fig. 43. Draw the half section in Fig. 45 as shown, and divide it into equal parts; drop perpendiculars as shown to the line *no*, and from these points draw lines to the apex *b*, which is obtained by extending the lines *nj'* and *oj* until they meet at *b*. Where the radial lines intersect the line *jj'* draw lines at right angles to the center line 3b, intersecting the side of the handle *o b* at 1', 2', 3', 4' and 5'. Now with *b* as a center and *bo* as a radius, describe the arc 1–1, upon which place twice the number of spaces contained in the half section *a*. From these points on 1–1 draw radial lines to *b* and cut them with arcs struck from *b* as center and radii equal to *b*1', *b*2', *b*3', *b*4' and *b*5'. Trace a line through points thus obtained to complete the pattern.

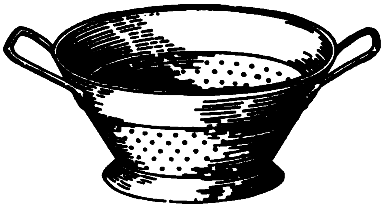


Fig. 46.

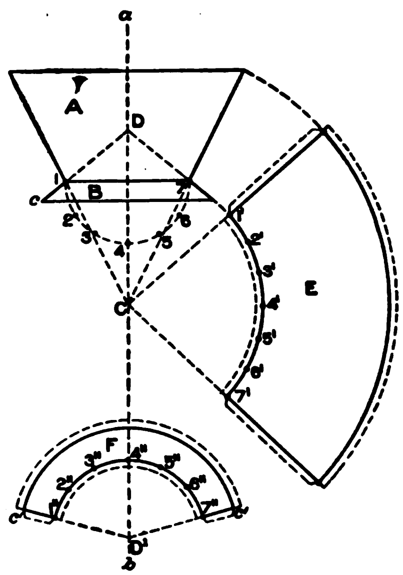
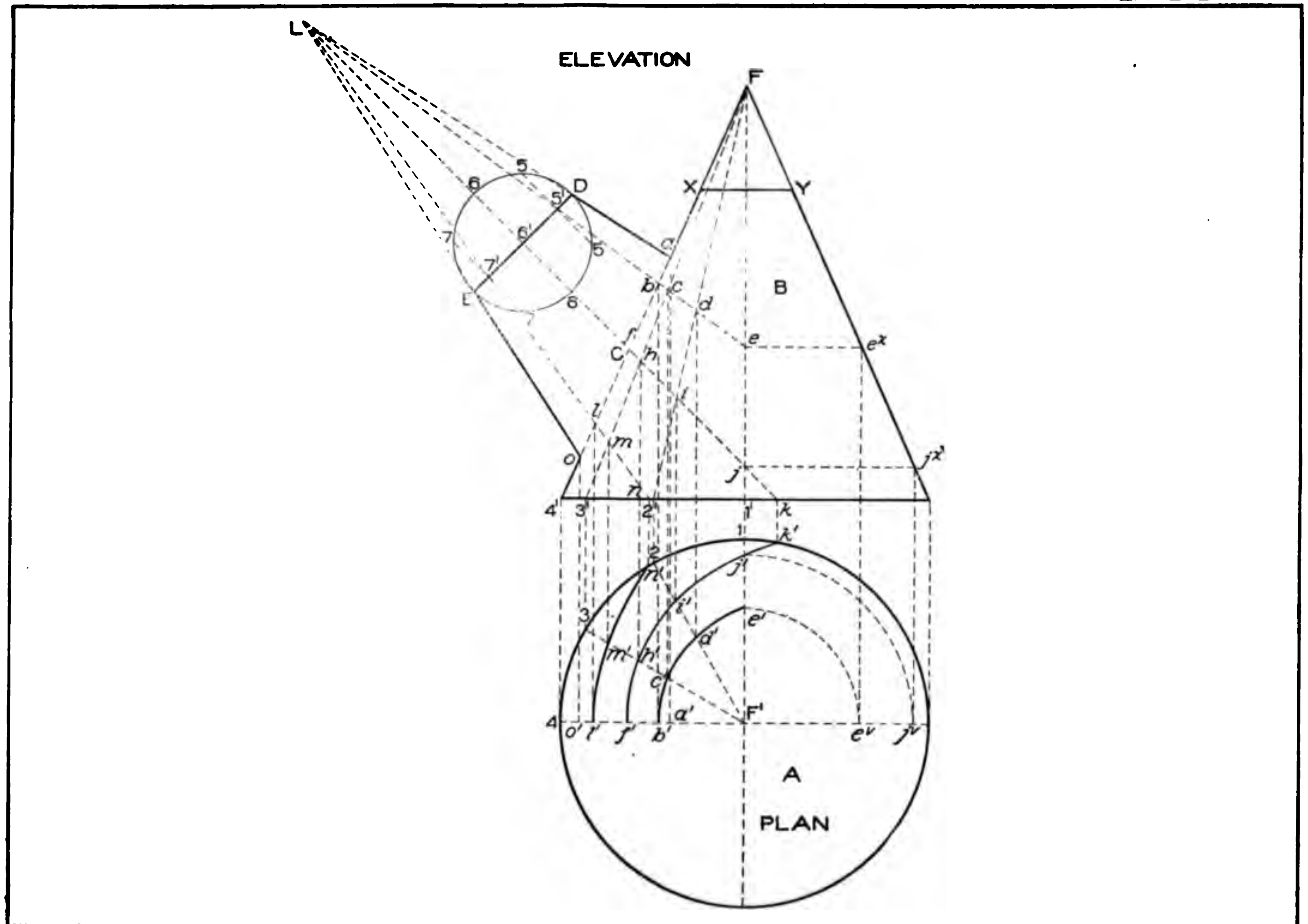



Fig. 47.

**Colander.** Fig. 46 shows another well-known form of tin ware, known as a colander. The top and bottom are wired and the foot and body seamed together, the handles of tinned malleable iron being riveted to the body. In Fig. 47 is shown how to lay out the patterns. Draw the elevation of the body A and foot B and extend the sides of the body and foot until they meet respec-

PLATE I



tively at C and D on the center line *ab*. Draw the half section on the line 1–7 and divide it into equal parts as shown. For the body, use C as a center and describe the arcs shown, laying off the stretchout on the lower arc, allowing edges in the usual manner. Then E will be the half pattern for the body. In the usual manner obtain the pattern for the foot shown at F, the pattern being struck from $D^1$ as center, with radii obtained from the elevation D1 and D*c*.

## PLATES.

In preparing the plates, the student should practice on other paper, and then send finished drawings for examination. The plates of this instruction paper should be laid out in the same manner and of the same size as the plates in Mechanical Drawing Parts I, II and III.

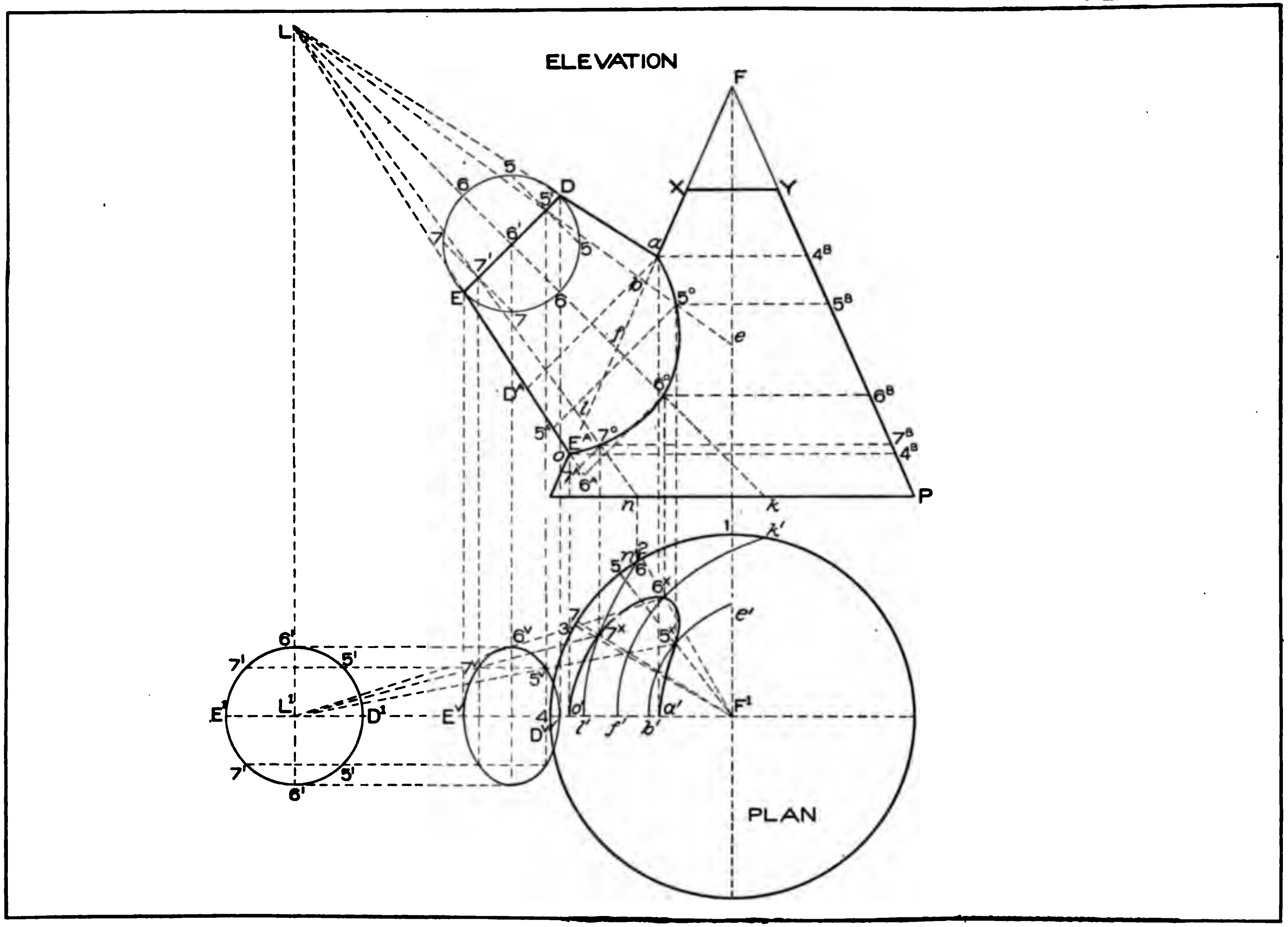
### PLATE I.

On this plate, the intersection between two right cones is shown. This problem arises in the manufacture of tinware in such instances as the intersections between the spout and body as in a teapot, watering pot, kerosene-oil can, dipper handle and body, and other articles. It is one of the most complicated problems arising in tinsmith work. The problem should be drawn in the center of the sheet making the diameter of the base A 4 inches and the height of the cone B 4½ inches. The distance from X to Y should be 1 inch. From the point F measure down on the side of the cone a distance of 3⅛ inches and locate the point C, from which draw the axis of the smaller cone at an angle of 45° to the axis of the larger cone. From C measure on CL 1⅝ inches locating the point 6′; through this point, at right angles to the axis, draw ED equal to 1½ inches. From the point 4′ on the base of the cone, measure up on the side of the cone a distance of ½ inch as indicated by *o*, and draw a line from *o* to E, extending it, until it intersects the axis LC at L. From L draw a line through D extending it until it intersects the larger cone at *a*. Then D *a o* E will represent the outline of the frustum of the smaller cone in elevation.

The next step is to obtain the line of intersection between the two cones, but before this can be accomplished, horizontal sections must be made through various planes of the smaller cone cutting into the larger. As the intersection of each half of the smaller cone with the larger one is symetrical, and as the small cone will not intersect the larger one to a depth greater than the point 1 in plan, divide only one-quarter of the plan into a number of equal spaces as shown by figures 1 to 4; from these points draw radial lines to the center $F^1$ as shown. Also from points 1, 2, 3 and 4 erect vertical lines intersecting the base of the cone at 1′, 2′, 3′ and 4′ respectively, from which points draw radial lines to the apex F.

Now with 6′ on the line ED as a center describe the circle shown, which represents the true section on ED. Divide each semi-circle into the same number of divisions as shown by the small figures D, 5, 6, 7, and E on either side. From these points at right angles to ED draw lines intersecting the center line ED at 5′. 6′ and 7′. From the apex L draw lines through the intersection 5′, 6′ and 7′, and extend them until they intersect the axis of the large cone at *e* and the base line at *k* and *n*. The student may naturally ask why the radial lines in the small cone are drawn to these points. As it is not known how far the smaller cone will intersect the larger one, we obtain such sections on the planes just drawn, as we think will be required to determine the depth of the intersection. Thus the radial line drawn through 5′ intersects the radial lines through 4′, 3′, 2′ and 1′ in the larger cone, at *b*, *c*, *d* and *e* respectively. The radial line through 6′ intersects radial lines in the larger cone at *f*, *h*, *i*, *j* and the base line at *k*, while the radial line drawn through the point 7′, intersects the radial lines of the larger cone at *l* and *m* and the base at *n*. We know that the line D*a* and E*o* of the smaller cone intersect the larger cone at points *a* and *o* respectively, and determine the true points of intersection; these are shown in plan by *a*′ and *o*′, and therefore no horizontal sections are required on these two planes. For the horizontal section on the plane *b e*, drop vertical lines from the intersections *b*, *c* and *d* on the radial lines, intersecting radial lines having similar numbers in plan as shown by *b*′, *c*′ and *d*′. To obtain the point of intersection in plan of *e* in elevation, draw from the point *e* a horizontal line intersecting the side of the cone at $e^x$, from which point drop a perpendicular line intersecting the center line in plan at $e^v$.

PLATE II



Then using $F^1e^v$ as radius, describe an arc intersecting the radial line 1 at $e'$. Through the points $e'$, $d'$, $c'$ and $b'$ draw a curved line, which is the half horizontal section of $b\ e$ in elevation. In the same manner obtain the sections shown in plan by $f'$, $h'$, $i'$, $j'$ and $k'$; and $l'$, $m'$ and $n'$, which have similar letters and figures in both plan and elevation. The next step is to obtain the intersections where the radial lines of the smaller cone will intersect these sections in plan just obtained. To avoid a confusion of lines which would otherwise occur, a reproduction of the plan and elevation has been transferred to Plate II.

## PLATE II.

The figures on this plate are similar to those on Plate I and have similar letters and figures; those letters and figures being omitted which are not necessary. This plate should be studied carefully before proceeding. The reproducing from Plate I can be best done by using a needle point or the small needle which is usually found in the handle of the drawing pen, when unscrewing the pen from the handle, and pricking through Plate I, very small indistinct prick marks. Omit all that is omitted in Plate II, where it will be noticed that the radial line in elevation, of the larger cone, and some of the various small letters in plan are not represented.

To obtain the plan view of the smaller cone, proceed as follows: Extend the line $F^1$ 4 in plan as shown by $F^1$ $E^1$. From the apex L of the smaller cone drop a vertical line intersecting $F^1$ $E^1$ at $L^1$, which represents the apex of the smaller cone in plan. With $L^1$ as center and radius equal to the radius 6′ D describe the circle $E^1$ $D^1$ and divide the circumference into the same number of spaces as ED, being careful to number the spaces as is there shown. The reason for doing this may be better understood from what follows: Assume that ED is a pivot on which the circle turns, so that it lies on a plane ED, then by looking down from the top, the points 6 and 6 appear as shown by 6′ and 6′ in plan.

A better illustration is obtained by cutting a card-board disc and after spacing it and numbering the points hold it in various positions until all the points become clear. Now from the intersections on ED in elevation, drop lines, intersecting horizontal lines drawn from similar numbered points in the profile $E^1$ $D^1$, thus obtaining the points of intersection $D^v$, $5^v$, $6^v$, $7^v$ and $E^v$. Trace a curved line through these points, which will give the the top view of ED. As the radial lines drawn through the points $5'$, $6'$ and $7'$ on the line ED of the smaller cone in elevation intersect the section lines *b e*, *f k* and *l n* respectively, the radial lines in plan drawn through the apex $L^1$ and points $5^v$, $6^v$, and $7^v$ must intersect similar section lines in plan $b' e'$, $f' k'$ and $l' n'$ respectively, as shown by points $5^x$, $6^x$ and $7^x$. The points $a'$ and $o'$ are obtained by dropping perpendiculars from the points *a* and *o* in elevation onto the line $E^1 F^1$ in plan. Through the points thus obtained, draw the curved line $a'$, $5^x$, $6^x$, $7^x$, $o'$ which will represent the plan view of one-half of the intersection between the two cones, the other half being similar.

Now from the intersections $5^x$, $6^x$ and $7^x$ on the section lines $b' e'$, $f' k'$ and $l' n'$ respectively, erect perpendicular lines intersecting similar section lines in elevation *b e*, *f k* and *l n* as shown respectively by points $5^\circ$, $6^\circ$ and $7^\circ$.

A curved line traced through *a*, $5^\circ$, $6^\circ$, $7^\circ$ and *o* will represent the line of intersection between the two cones in elevation. At right angles to the axis of the smaller cone and from the intersections *a*, $5^\circ$, $6^\circ$ and $7^\circ$ draw lines intersecting the side of the cone E *o* at $D^A$ $5^A$ $6^A$ and $7^A$. For the pattern of the smaller cone proceed as is shown in the following plate:

## PLATE III.

On this plate the two patterns should be placed in the center of the sheet. Take the radius of LD in Plate II and with L in Fig. 1 of Plate III as center describe the arc DD. From L drop a vertical line as shown by L $E^A$. Upon the arc DD measuring from either side of the point E, lay off the stretchout of the semi-circle E, 7, 6, 5, D in Plate II as shown by similar letters and figures on DD in Fig. 1 Plate III. From the apex L and through these points draw radial lines as shown and intersect them by arcs whose radii are equal to L $D^A$, L $5^A$, L $6^A$, L $7^A$ and L $E^A$ in Plate II, as shown by similar letters and figures in Plate III. Trace a line through points thus obtained, and D, E, D, $D^A$, $E^A$, $D^A$, D will be the pattern for the small cone. As the pattern for the larger cone is obtained in the usual manner, we will only show how to obtain the opening to be cut into one side of the larger

PLATE III

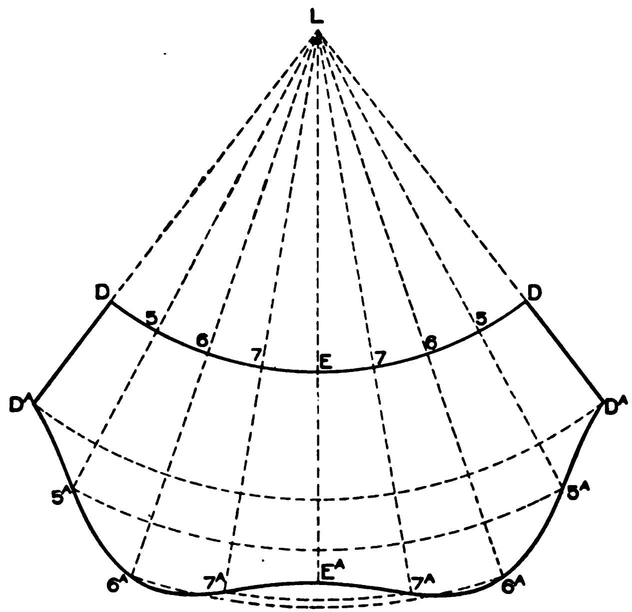



FIG. 1

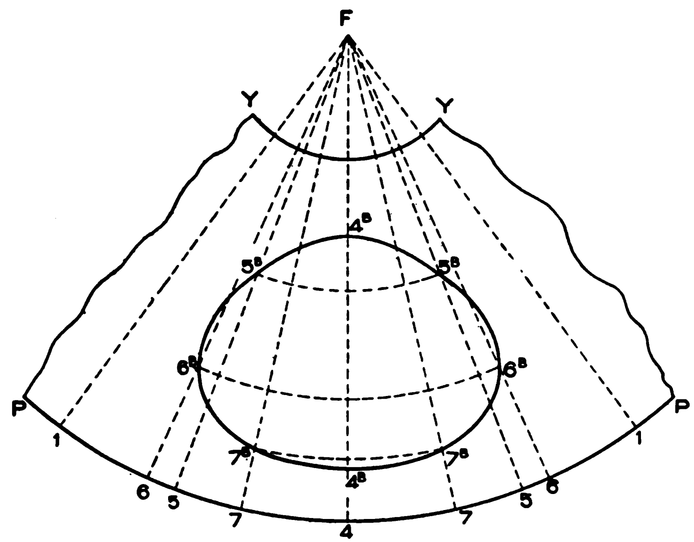
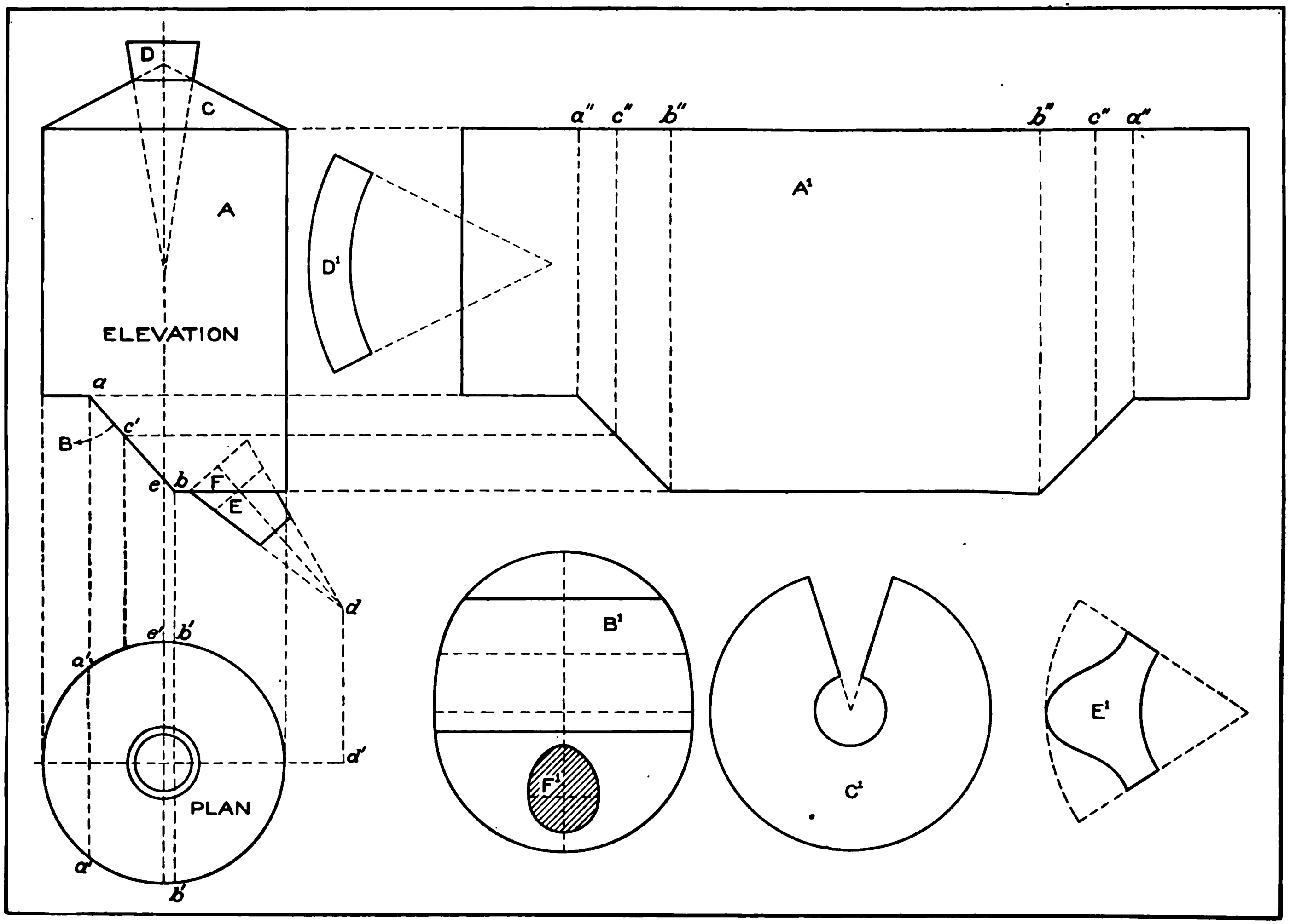



FIG. 2

PLATE IV



cone to admit the intersection of the smaller. We must now again refer to Plate II. From the intersections $a$, $5^o$, $6^o$, $7^o$, and $o$ in elevation draw lines at right angles to the line of the axis, intersecting the side of the cone at $4^B$, $5^B$, $6^B$, $7^B$ and $4^B$.

Also in addition to the spaces 1, 2, 3 and 4 in the plan view, it will be necessary to obtain the points of intersection on the base line in plan, where the radial lines would intersect drawn from the apex $F^1$ through the points of intersections between the two cones. This is accomplished by drawing lines from $F^1$ through $5^x$; $6^x$ and $7^x$ until they intersect the base line in plan at 5, 6 and 7. All these points form the basis with which to develop the pattern shown in Fig. 2 of Plate III, in which draw the vertical line F 4, and with F as a center and radii equal to FY, and F P in Plate II draw the arcs YY and PP in Fig. 2 of Plate III as shown. Now starting from the point 4 on the arc PP on either side, lay off the stretchout of 1, 6, 5, 7 and 4 in plan in Plate II as shown by similar numbers in Fig. 2 of Plate III. From the points 6, 5, 7 and 4 on either side draw radial lines to the apex F, which will be used to obtain the pattern for the opening. Now with F as center and radii equal to F $4^B$, F $5^B$, F $6^B$, F $7^B$ and F $4^B$ in Plate II, describe arcs intersecting radial lines having similar numbers in Fig. 2 of Plate III as shown by intersections having similar numbers. A line traced through these points will be the required opening to be cut out of the pattern of the larger cone, one-half of which is shown by drawing radial lines from the points 1 and 1 to the apex F.

## PLATE IV.

In drawing this plate, the same size paper and border lines should be used as for the preceding plates. The subject for this plate is an oil tank resting on inclined wooden racks. The problem involves patterns in parallel and radial-line developments.

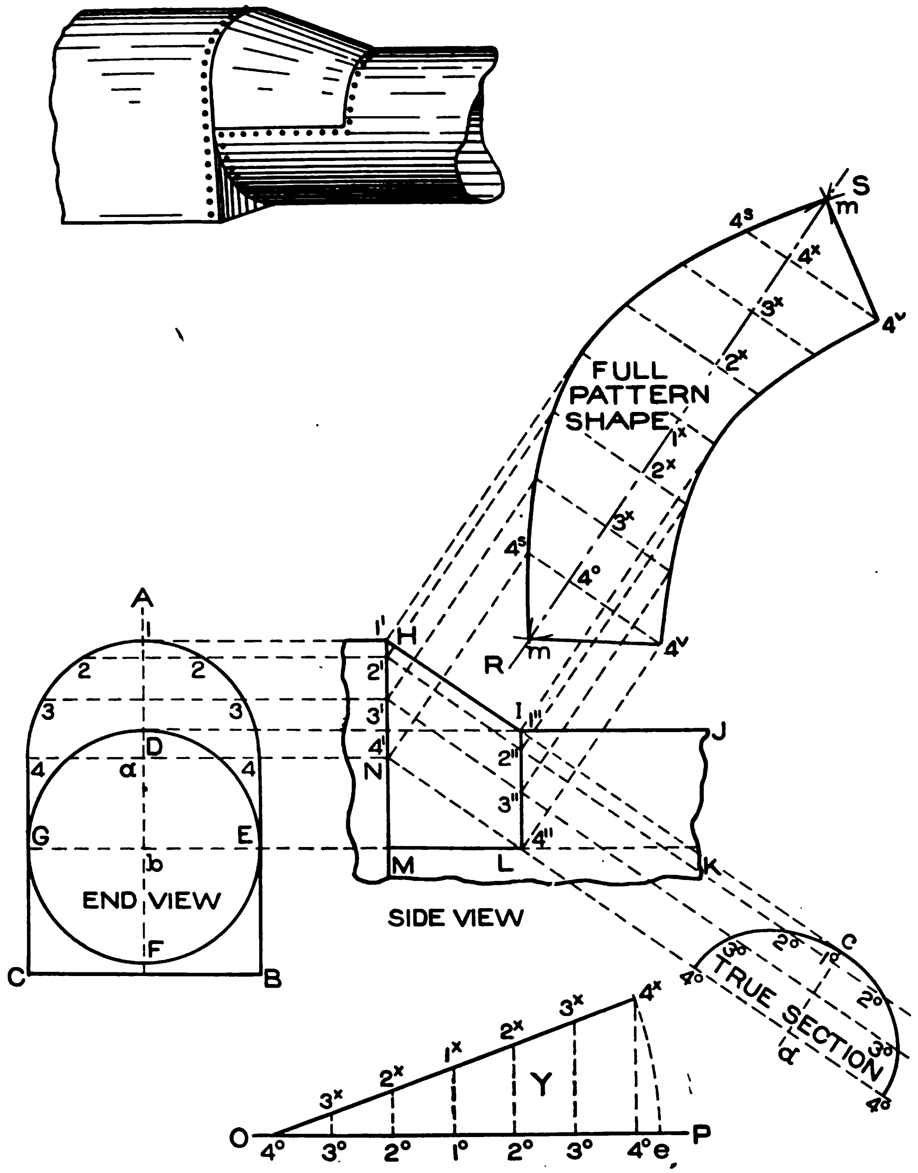
## TABLE OF STANDARD OR REGULAR TIN PLATES.

**Size and Kind of Plates, Number and Weight of Sheets in a Box, and Wire Guage Thickness, of Every Kind and Size.**

| Size. | Grade. | Sheets in Box. | Pounds in Box. | Wire Guage. |
|---|---|---|---|---|
| 10 x 10 | IC | 225 | 80 | 29 |
| " | IX | 225 | 100 | 27 |
| " | IXX | 225 | 115 | 26 |
| " | IXXX | 225 | 130 | 25 |
| " | IXXXX | 225 | 145 | 24 1-2 |
| 10 x 14 | IC | 225 | 112 | 29 |
| " | IX | 225 | 140 | 27 |
| " | IXX | 225 | 161 | 26 |
| " | IXXX | 225 | 182 | 25 |
| " | IXXXX | 225 | 203 | 24 1-2 |
| " | IXXXXX | 225 | 224 | 24 |
| " | IXXXXXX | 225 | 245 | 23 1-2 |
| 10 x 20 | IC | 225 | 160 | 29 |
| " | IX | 225 | 200 | 27 |
| 11 x 11 | IC | 225 | 95 | 29 |
| " | IX | 225 | 121 | 27 |
| " | IXX | 225 | 139 | 26 |
| " | IXXX | 225 | 157 | 25 |
| " | IXXXX | 225 | 175 | 24 1-2 |
| 11 x 15 | SDC | 200 | 168 | 26 |
| " | SDX | 200 | 189 | 25 |
| " | SDXX | 200 | 210 | 24 1-2 |
| 11 x 15 | SDXXX | 200 | 230 | 24 |
| 12 x 12 | IC | 225 | 112 | 29 |
| " | IX | 225 | 140 | 27 |
| " | IXX | 225 | 161 | 20 |
| " | IXXX | 225 | 182 | 25 |
| " | IXXXX | 225 | 203 | 24 1-2 |
| " | IXXXXX | 225 | 224 | 24 |
| " | IXXXXXX | 225 | 245 | 23 1-2 |
| 12 1-2 x 17 | DC | 100 | 98 | 28 |
| " | DX | 100 | 126 | 26 |
| " | DXX | 100 | 147 | 24 |
| " | DXXX | 100 | 168 | 23 |
| " | DXXXX | 100 | 189 | 22 |
| " | DXXXXX | 100 | 210 | 21 |
| 13 x 13 | IC | 225 | 135 | 29 |
| " | IX | 225 | 169 | 27 |
| " | IXX | 225 | 194 | 26 |
| " | IXXX | 225 | 220 | 25 |
| " | IXXXX | 225 | 245 | 24 1-2 |
| 13 x 17 | IXX | 225 | 254 | 26 |
| 13 x 18 | IX | 225 | 234 | 27 |
| " | IXX | 225 | 269 | 26 |
| 14 x 14 | IC | 225 | 157 | 29 |
| " | IX | 225 | 196 | 27 |
| " | IXX | 225 | 225 | 26 |
| " | IXXX | 225 | 255 | 25 |

## TABLE OF STANDARD OR REGULAR TIN PLATES.---Con.

| Size. | Grade. | Sheets in Box. | Pounds in Box. | Wire Gauge. |
|---|---|---|---|---|
| 14 x 14 | IXXXX | 255 | 284 | 24 1-2 |
| 14 x 17 | IX | 225 | 238 | 27 |
| 14 x 20 | IC | 112 | 113 | 29 |
| " | IX | 112 | 143 | 27 |
| " | IXX | 112 | 162 | 26 |
| " | IXXX | 112 | 183 | 25 |
| " | IXXXX | 112 | 202 | 24 1-2 |
| 15 x 15 | IX | 225 | 225 | 27 |
| " | IXX | 225 | 259 | 26 |
| " | IXXX | 225 | 293 | 25 |
| " | IXXXX | 225 | 326 | 24 1-2 |
| 15 x 21 | IX | 112 | 158 | 27 |
| " | DXX | 100 | 218 | 24 |
| " | DXXX | 100 | 249 | 23 |
| " | DXXXX | 100 | 280 | 22 |
| 15 x 22 | IXX | 112 | 190 | 26 |
| " | SDXX | 100 | 210 | 24 1-2 |
| " | SDXXX | 100 | 230 | 24 |
| 16 x 16 | IC | 225 | 205 | 29 |
| " | IX | 225 | 256 | 27 |
| " | IXX | 225 | 294 | 26 |
| " | IXXX | 225 | 333 | 25 |
| " | IXXXX | 225 | 371 | 24 1-2 |
| 17 x 17 | IC | 225 | 231 | 29 |
| 17 x 17 | IX | 225 | 289 | 27 |
| " | IXX | 112 | 166 | 26 |
| " | IXXX | 112 | 188 | 25 |
| " | IXXXX | 112 | 210 | 24 1-2 |
| 17 x 25 | DC | 100 | 196 | 28 |
| " | DX | 100 | 252 | 26 |
| " | DXX | 50 | 146 | 24 |
| " | DXXX | 50 | 168 | 23 |
| " | DXXXX | 50 | 189 | 22 |
| " | IX | 112 | 213 | 27 |
| " | IXX | 112 | 244 | 26 |
| 18 x 18 | IX | 112 | 162 | 27 |
| " | IXX | 112 | 186 | 26 |
| " | IXXX | 112 | 211 | 25 |
| " | IXXXX | 112 | 235 | 24 1-2 |
| 19 x 19 | IC | 112 | 144 | 29 |
| " | IX | 112 | 180 | 27 |
| " | IXX | 112 | 207 | 26 |
| " | IXXX | 112 | 234 | 25 |
| " | IXXXX | 112 | 262 | 24 1-2 |
| 20 x 20 | IC | 112 | 160 | 29 |
| " | IX | 112 | 200 | 27 |
| " | IXX | 112 | 230 | 26 |
| " | IXXX | 112 | 260 | 25 |
| " | IXXXX | 112 | 290 | 24 1-2 |
| 20 x 28 | IC | 112 | 224 | 29 |
| " | IX | 112 | 280 | 27 |
| " | IXX | 112 | 322 | 26 |




PATTERN FOR GUSSET SHEET OF BOILER, SHOWING DEVELOPMENT.

# SHEET-METAL WORK.

The sheet-metal worker of today who wishes to succeed must know far more than was necessary years ago. There are many good, practical sheet-metal workers in the trade who are handicapped because they are unable to lay out the patterns that arise in their daily work. Notwithstanding the introduction of labor-saving machinery, the demand for good workmen has increased. While most sheet-metal workers acquire practical knowledge in the shop, they lack the technical education necessary to enable them to become proficient as pattern cutters and draftsmen. In this course, special attention is given to the fundamental principles that underlie the art and science of pattern drafting.

Practical workshop problems will be presented, such as arise in everyday practice, thus giving the student the practical experience that usually comes only after long association with the trade

## CONSTRUCTION.

In constracting the various articles made from sheet metal, various gauges or thicknesses of metal are used. For all gauges from No. 20 to No. 30 inclusive, we assume in the development of the pattern, that we are dealing with no thickness, and we make no allowance for bending or rolling in the machine. But where the metal is of heavier gauge than No. 20, allowance must be made for shrinkage of the metal in the bending and rolling operations, which will be explained in connection with development in heavy sheet-metal work. What has been said about wiring, seaming, and transferring patterns in the Tinsmith's Course is applicable to this course also. It is sometimes the case that the capacity of a vessel or article must be determined, when the rules given in Mensuration should be followed. When figuring on sheet-metal work, the specifications sometimes call for various metals, such as galvanized sheet iron or steel, planished iron, heavy boiler plate, band iron, square or round rods for bracing, etc., zinc, copper, or brass; and the weight of the metal must often be calculated together with that of stiffening rods, braces, etc. On this account it is necessary to have tables which can be consulted for the various weights.

## TABLES.

There is a wide difference between gauges in use, which is very annoying to those who use sheet metal rolled by different firms according to the various gauges adopted. It would be well to do away with gauge numbers, and use the micrometer caliper shown in Fig. 1, which determines the thickness of the metal by the decimal or fractional parts of an inch.

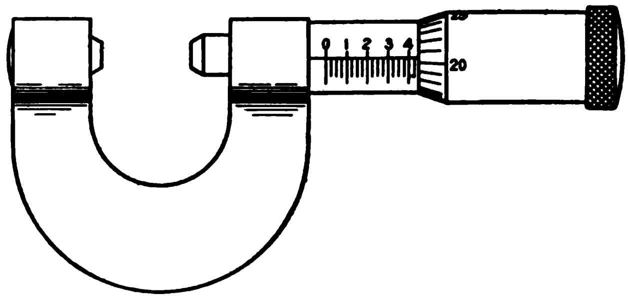



Fig. 1.

This is the most satisfactory method for the average mechanic who works sheet metal manufactured by firms using different gauges. The tables on pages 61 to 74 can be consulted when occasion arises.

## SHOP TOOLS.

In allowing edges for seaming and wiring, we must bear in mind that when a seam is to be grooved by hand or machine the allowance to be made to the pattern should conform to the rolls in the machine or the hand tools in use. The edges of the pattern are usually bent on the sheet-iron folder, or brake, while the seam can be seamed or grooved with the hand groover or giant grooving machine. Where round pipe work is done in lengths up to 3 feet, the slip roll former is used, while square or rectangular pipes are bent up on the brake in 8-foot lengths. Where pipes, elbows, stove bodies, furnace shells, metal drums, etc., are made, the sheets are cut square on the large squaring shears, rolled, grooved, and stiffened, by beading both ends in the beading machine, using ogee rolls. There is also a special machine for seaming the cross seams in furnace pipes, also a set of machines for the manufacture of elbows used in sheet-metal work. As before mentioned, if these machines are at hand, it will be well to make slight modifications in the patterns so that both the machines and patterns may work to advantage.

## PATTERNS OBTAINED BY VARIOUS METHODS.

In this course will be explained the four methods used in developing patterns for sheet-metal work, namely, parallel line, radial line, triangulation, and approximate developments. What was said on parallel and radial line developments in the Tinsmith's Course is applicable to this course also.

## INTERSECTIONS AND DEVELOPMENTS.

The following problems on parallel line developments have been selected because they have a particular bearing on pipe work arising in the sheet-metal trade. All of the problems that will follow should be carefully studied, drawn on cheap paper, and proven by cardboard models. These models will at once show any error in the patterns which might otherwise be overlooked. As only the Examination Plates are to be sent to the School, the student should draw all the other plates given in this course.

The first problem to be drawn is shown in Fig. 2, being the intersection between a cylinder and octagonal prism. In drawing these problems for practice, make the cylinder and octagonal prism both 2 inches in diameter. The height of the cylinder from B to E should be $4\frac{1}{2}$ inches; and the length of the prism from G to H, 3 inches. Let A represent the plan of the cylinder, shown in elevation by B C D E; and F, the section of the prism, shown in plan by G H I J. Number the corners of the section F as shown, from 1 to 4 on both sides; and from these points draw horizontal lines intersecting the plan of the cylinder at 2′3′ and 1′4′ on both sides as shown. Establish a convenient intermediate point of intersection between the corners of the prism, as *a* and *a* in A, from which draw horizontal lines intersecting the section F at $a'$, $a'$, $a'$, and $a'$. Take a tracing of the section F with its various intersections, and place it in its proper position as shown by $F^1$, in the

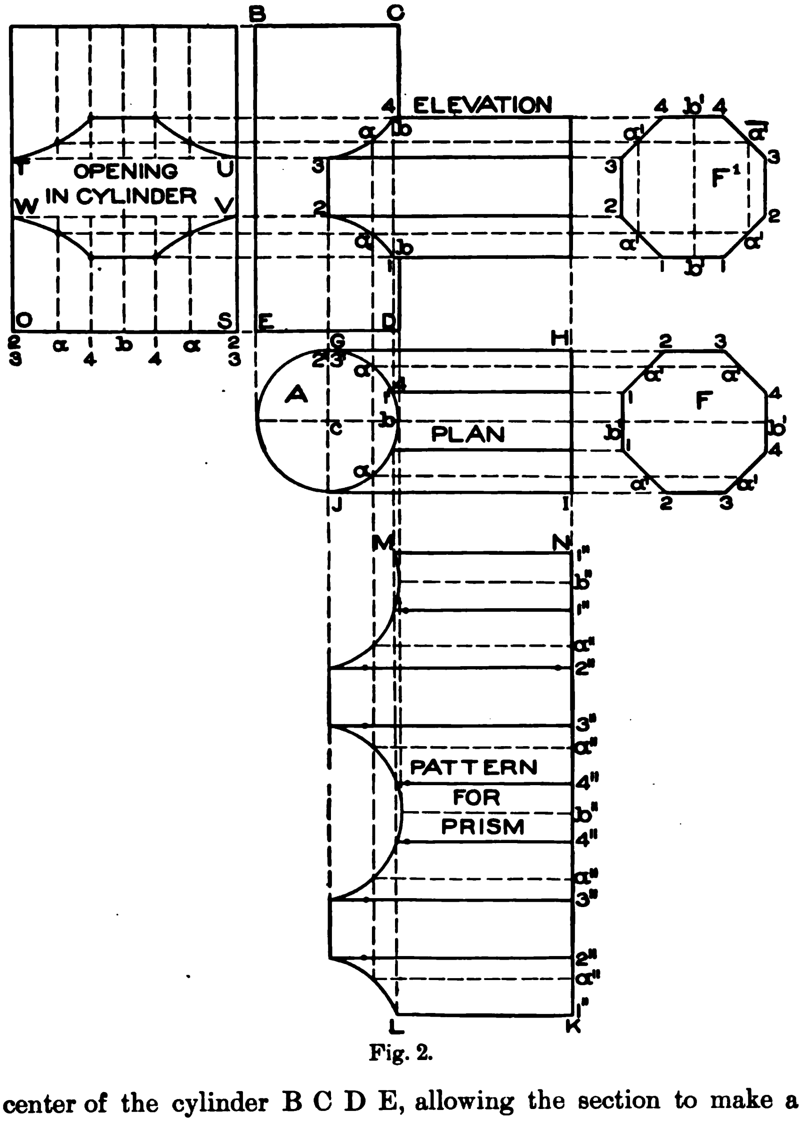



Fig. 2.

center of the cylinder B C D E, allowing the section to make a quarter turn, and bringing the points $b'$ $b'$ at the top and bottom on a vertical line, while in the section F, $b'$ $b'$ are on a horizontal line. From the various intersections in $F^1$, draw horizontal lines intersecting vertical lines drawn from similarly numbered intersections in the plan A, as shown in elevation. A line drawn through these points will represent the joint between the cylinder and prism.

For the development for the prism, extend the line H I in plan as N K, upon which place the stretchout of all the points contained in the section F, as shown by similar figures and letters on N K. Through these points, at right angles to N K, draw lines which intersect with lines drawn from similarly numbered points and letters in plan, at right angles to J I. Trace a line through points thus obtained, and K L M N will be the desired pattern. To obtain the development for the opening in the cylinder, extend the line D E in elevation as S O, upon which place the stretchout of all the points contained in the half-circle A, as shown by similar numbers and letters on S O. At right angles to S O and through these points, draw lines intersecting horizontal lines drawn from intersections having similar numbers and letters in elevation, thus obtaining the intersections shown by T U V W, which will be the shape of the opening to be cut into one-half of the cylinder.

In Fig. 3 is shown the intersection between a hexagonal and quadrangular prism, the hexagonal prism being placed in elevation at an angle of 45° to the base line. When drawing this problem for practice, make the height of the quadrangular prism $4\frac{1}{2}$ inches, and each of its sides 2 inches. Place the hexagonal prism at an angle of 45° to the base line, placing it in the center of the quadrangular prism in elevation as shown; and inscribe the hexagonal section in a circle whose diameter is $2\frac{1}{2}$ inches. Let A represent the plan of the quadrangular prism placed diagonally as shown, above which draw the elevation B C D E. In its proper position and proper angle, draw the outline of the hexagonal prism as shown by $1^v$ 1″ 4″ $4^v$; and on 1″ 4″ draw the half section as shown by F, numbering the corners 1″ 2″ 3″ and 4″. From the corner 1′ in the plan A, draw the center line 1′ 4. Take a tracing of the half section F, and place it as shown by $F^1$, placing the points 1″ 4″ in F on the center line in $F^1$ as shown. From the corners 1, 2, 3, and 4, draw lines parallel to the center line, intersecting the two sides of A (*b* 1′ and 1′ *a*) at 2′ 3′ and 1′ 4′, as shown. From these intersections draw vertical lines, which intersect by lines drawn parallel to $4'\ 4^{v}$ from corners having similar numbers in F, thus obtaining the points of intersection $1^{v}\ 2^{v}\ 3^{v}$ and $4^{v}$. Dropping vertical lines from the intersections on the plane $1'\ 4'$ in elevation, and intersecting similarly numbered lines in plan, will give the horizontal section of $1'\ 4'$, as shown by $1^{\circ}\ 2^{\circ}\ 3^{\circ}$ and $4^{\circ}$.

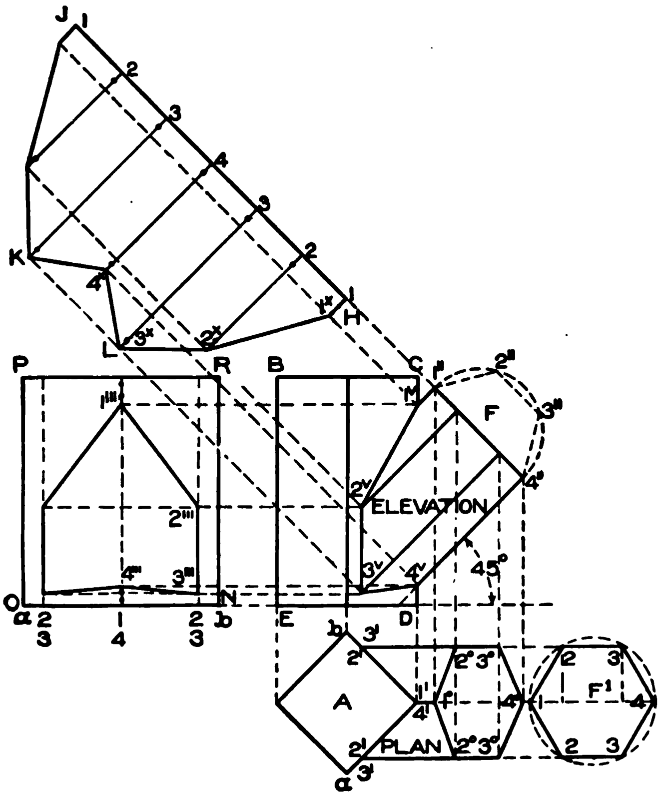



Fig. 3.

For the development of the hexagonal prism, extend the line $4'\ 1'$ as shown by H J, upon which place the stretchout of twice the number of spaces contained in the half section F, as shown by similar figures on the stretchout line H J. From these points, at right angles to H J, draw lines as shown, which intersect by lines drawn at right angles to the line of the prism from intersections $1^{v}$ to $4^{v}$, thus obtaining the points of intersection $1^{x}$ to $4^{x}$. Lines traced from point to point as shown by J K L H, will be the required development. The shape of the opening to be cut into the quadrangular prism, is obtained by extending the line D E in elevation as N O, upon which place the stretchout of one-half the section A, with the various points of intersection, as shown by similar figures on O N. At right angles to O N erect lines from these points, which intersect by lines drawn from similarly numbered intersections in elevation at right angles to the quadrangular prism, thus obtaining the points of intersection 1‴ to 4‴ on both sides. Then N O P R will be the half development.

Fig. 4 shows the intersection between two cylinders of equal diameters at right angles. Make the height of the vertical cylinder 3 inches, that of the horizontal cylinder 1¼ inches, and the diameters of both 2 inches. Let A represent the plan of the vertical cylinder, and B its elevation. Draw the plan of the horizontal cylinder C, shown in elevation by D placed in the center of the vertical cylinder. Draw the half section E in plan and divide it into equal parts, as shown from 1 to 3 to 1. In a similar manner draw the half section $E^1$ in elevation, which also divide into the same number of spaces as E, reversing the numbers as shown.

The following suggestions are given to avoid confusion in numbering the points or corners of irregular or round sections in plan and elevation. If the half section E were bent on the line 1–1 and turned upward toward the reader, and we should view this section from the front, the point 3 would be at the top, or, if bent downward, would be at the bottom; therefore the points 3 and 3 in elevation are placed at top and bottom. Now if the section $E^1$ in elevation were bent on the line 3-3 either toward or away from the reader, the point 1 when looking down would show on both sides as shown in plan, which proves both operations. No matter whether the form is simple, as here shown, or complicated as that which will follow, the student should use his imaginative power. Study the problem well; close your eyes and imagine you see the finished article before you, or, failing in this, make a rough model in the shop or a cardboard model at home, which will be of service. Now from the intersections in E, draw horizontal lines intersecting the circle A at 1′, 2′ and 3′ on both sides. From these points erect perpendicular lines and intersect them with horizontal lines drawn

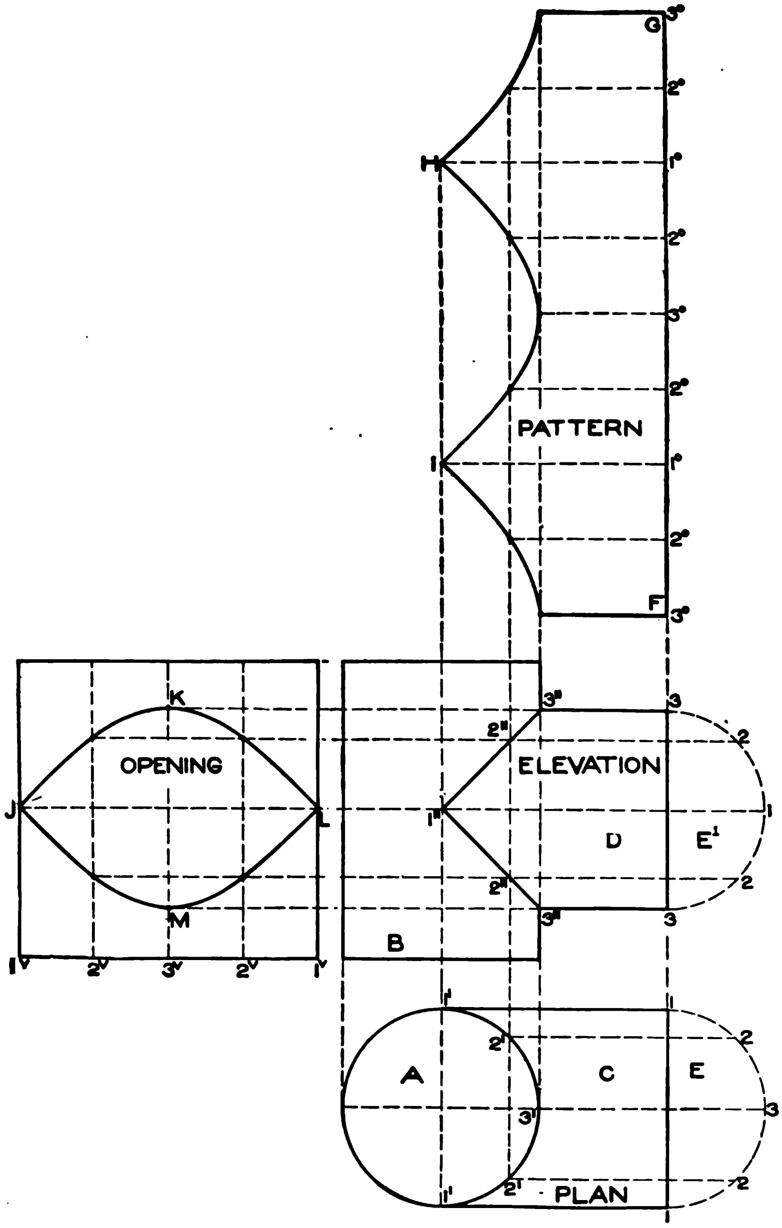



Fig. 4.

from similarly numbered intersections in $E^1$. Lines traced through these points 3′ 2′ 1′ and 1′ 2′ 3′ will be straight because both branches are of equal diameters.

For the development of the cylinder D in elevation, extend the line 3-3 as shown by F G, upon which place the stretchout of twice the number of spaces contained in $E^1$, as shown by similar numbers 3° to 1° to 3° to 1° to 3° on the stretchout line F G. From these points, at right angles to G F, draw lines, and intersect them by lines drawn parallel to the cylinder B from similar numbers in the joint line. Trace a line through these points in the development, when F G H I will be the desired shape.

For the opening to be cut into the cylinder B to receive the cylinder D, extend the base of the cylinder B as shown by $1^v$ $1^v$, upon which place the stretchout of the half circle A in plan, as shown by similar figures on the stretchout line $1^v$ $1^v$. From these points erect perpendiculars, which intersect by lines drawn from similarly numbered intersections in elevation at right angles to the line of the cylinder B. Trace a line through the intersections thus obtained; J K L M will be the shape of the opening.

Fig. 5 shows the intersection of two cylinders of unequal diameters at an angle of 45°. Make the diameters of the large and small cylinders 2 inches and 1¼ inches respectively; the height of the large cylinder 3 inches; and the length of the small cylinder measured from its shortest side in elevation, 1 inch, placed at an angle of 45° in the center of the cylinder B. A represents the plan of the large cylinder struck from the center *a* and shown in elevation by B. Draw the outline of the small cylinder C at its proper angle, and place the half section D in its position as shown; divide it into a number of equal spaces, as shown from points 1 to 5. Through the center *a* in plan. draw the horizontal line *a* 5; and with *b* as a center describe a duplicate of the half section D with the various points of intersection, as shown by $D^1$, placing the points 1 and 5 on the horizontal line *a* 5. From the intersections in $D^1$ draw horizontal lines intersecting the large circle A at 3′ to 3′ as shown, from which points erect perpendicular lines; intersect them by lines drawn parallel to the lines of the smaller pipe from similarly numbered intersections in D. A line traced through the points thus obtained will represent the intersection or miter joint between the two pipes.

These same principles are applicable no matter what diameters the pipes have, or at what angle they are joined, or whether the

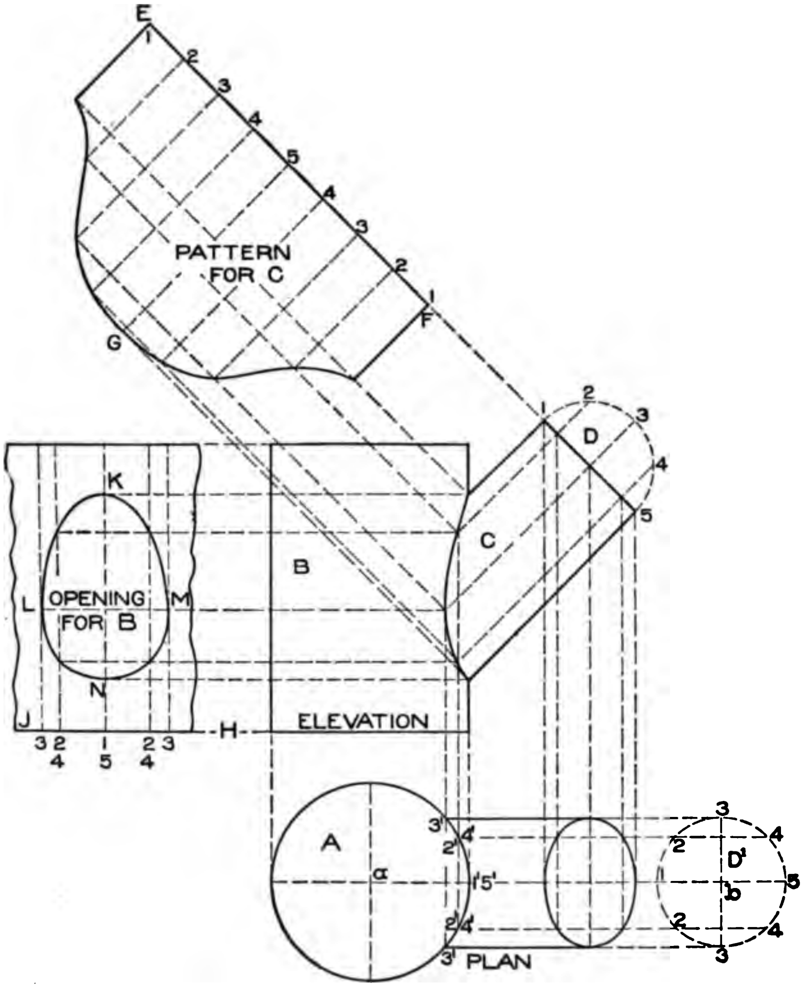



Fig. 5.

pipe is placed as shown in plan or at one side of the center line.

For the development of the small cylinder extend the line 5 - 1 in elevation as shown by F E, upon which place the stretchout of the circle $D^1$ in plan, or twice the amount of D in elevation, as shown by similar figures on the stretchout line F E. At right angles to F E and through these small figures, draw lines which intersect with lines drawn at right angles to the lines of the small cylinder from similarly numbered intersections in the miter line in elevation. Trace a line through the points thus obtained; E F G will be the development for the cylinder C.

To obtain the opening in the large cylinder extend the lines of the large cylinder in elevation as shown at the base by H J, upon which place the stretchout of the intersections contained in the circle A, being careful to transfer each space separately (as they are unequal) to the stretchout line H J. Through these points and at right angles to H J erect lines which intersect with horizontal lines drawn from similar points in the miter line in elevation A line traced through the points thus obtained, as shown by K L M N, will be the desired development.

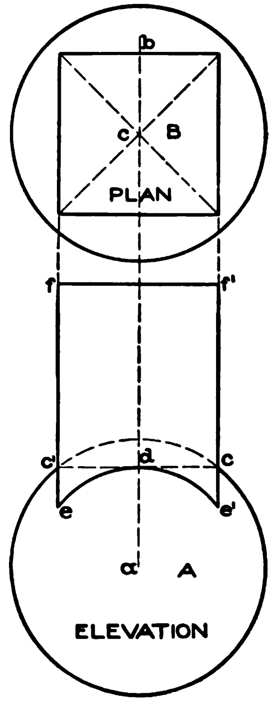


Fig. 6.

Fig. 6 shows the intersection between a quadrangular prism and sphere, the center of the prism to come directly over the center of the sphere. Make the diameter of the sphere $2\frac{1}{2}$ inches, the sides of the prism $1\frac{1}{2}$ inches, and the height from *f* to *c′* $2\frac{3}{8}$ inches. Draw the elevation of the sphere A which is struck from the center *a*, from which erect the perpendicular *a b*. With any point, as *c*, as a center and using the same radius as that used for A, describe the plan B. Through *c* draw the two diagonals at an angle of 45°, and draw the plan of the prism according to the measurements given. Now draw the elevation of the prism *f c′* and *f′ c*, the sides of the prism intersecting the sphere at *c* and *c′*. From either of these points draw a horizontal line intersecting the center line *a b* at *d*. Then using *a* as a center and *a d* as the radius, describe the arc *e e′* intersecting the sides of the prism extended at *e* and *e′*; *f e e′ f′*

will be the development for one of the sides of the prism. In practice the four sides are joined in one.

Fig. 7 shows the intersection of a quadrangular prism and sphere when the center of the prism is placed to one side of the center of the sphere. Make the diameter of the sphere the same as in the preceding figure; through *x* in the plan draw the 45° diagonal, and make the distance from *x* to A ½ inch, the sides of the prism 1 inch, and the height from E to *c* in elevation 1½ inches.

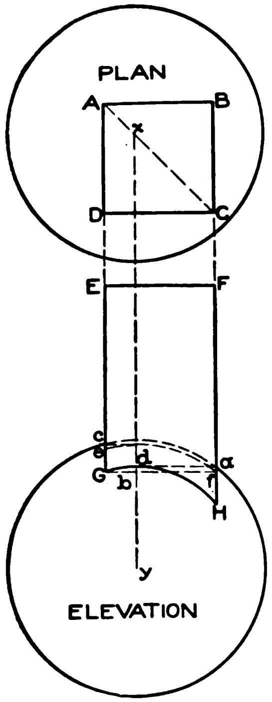



Fig. 7.

Having drawn the elevation and plan of the sphere, construct the plan of the prism as shown by A B C D. Parallel to the center line *x y* project the prism in elevation intersecting the sphere at *a* and *c*. Now since the center of the sphere is on one of the diagonals of the prism in plan, either two of the sides meeting at one end of that diagonal, as B C and C D, will be alike, and both will be different from the other two sides A B and A D, meeting at the opposite end of the diagonal. Therefore the line F *a* in elevation will be used in obtaining the development of D C in plan, while the line E *c* will be used in obtaining the development for the two sides D A and A B in plan.

Now from *a* draw a horizontal line intersecting the center line *x y* at *b*; and using *y* as a center and *y b* as the radius, describe the arc G H intersecting the sides of the prism extended to G and H. Then E F G H is the development for each side of the prism shown in plan by D C and C B. In a similar manner, from the intersection *c* in elevation draw a horizontal line intersecting the center line *x y* at *d*. Then using *y* as center and *y d* as radius, describe an arc intersecting the sides of the prism at *e* and *f*. E F *f e* will show the development for either side of the prism shown in plan by D A and A B. By connecting the points G and *f* it will be found that the line is a true horizontal line, which proves the two developments. Should the plan of the prism be so placed on the sphere that all sides would be different, then two elevations would be necessary so that the intersections of all the sides could be shown.

**Developments by Triangulation.** In developing sheet-metal work of irregular forms, patterns are required which cannot be developed by either the parallel or radial-line methods. These irregular shapes are so formed that although straight lines can be drawn upon them the lines would not run parallel to one another, nor would they all incline to a common center. In the methods previously described, the lines in parallel developments run parallel to one another, while in radial-line developments all the lines meet at a common center. Hence in the development of any irregular article, it becomes necessary to drop all previous methods, and simply proceed to measure up the surface of the irregular form, part by part, and then add one to another until the entire surface is developed. To accomplish this, one of the simplest of all geometrical problems is made use of and shown in Part II of Mechanical Drawing, Plate V, Problem 11, entitled "To construct a triangle having given the three sides." To carry out this method it is necessary only to divide the surface of the plan or elevation of any irregular article into a number of equal parts. Use the distances in plan as the bases of the triangles, and the distances in elevation as the altitudes or heights of the triangles, or *vice versa;* and then find the hypothenuse by connecting the two given lengths.

To illustrate this simple principle Fig. 8 has been prepared. Let A B C D represent the plan of a plane surface, shown in elevation by $A^1$ $B^1$. We know that the true length of the plane is equal to $A^1$ $B^1$ and the true width is equal to A D or B C in plan. We also know that the vertical height from the bottom of the plane $A^1$ to the top $B^1$ is equal to $B^1$ *b* as shown. But suppose we want to obtain the true length of the diagonal line B D in plan on the developed plane. To obtain this it will be necessary only to take the length of B D, place it from *b* to $D^1$, and draw a line as shown from $B^1$ to $D^1$, which is the length desired.

While this may look very simple, it is all that there is to triangulation, and if the student thoroughly understands the simple principle and studies the problems which will follow, he will have no trouble in applying this principle in complicated work. To make it still clearer we will prove the length of the line $B^1$ $D^1$. Take the distance of $A^1$ $B^1$, place it in plan as shown by A $B^2$, and complete the rectangle A $B^2$ $C^2$ D. Draw the diagonal $B^2$ D, being the length sought, which will be found to equal $B^1$ $D^1$ in elevation. When drawing this problem in practice, make the plan 4 by 6 inches and the vertical height in elevation 5 inches.

In obtaining developments by triangulation. the student should use all of his conceptive powers as previously explained. Before making any drawing, he must see the article before him in his mind's eye, so to speak, before he can put it down on paper. Therefore we want to impress upon the student the necessity of drawing all the problems that will follow in this part and in the Practical Workshop Problems. It should be understood that triangulation is not given as an alternative method, but is used when no other method can be employed, and without it no true pattern could be obtained for these irregular shapes; hence the necessity of close study.

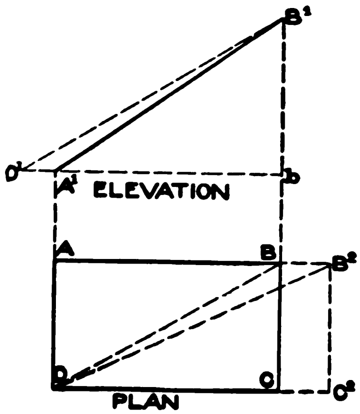


Fig. 8.

In Fig. 9 is shown an irregular solid whose base and top are triangles crossing each other, and in which the principle just explained will be put to practical test Inscribe the triangles shown in plan in a circle whose radius is equal to *a* 1, or $1\frac{1}{2}$ inches, and make the height of the article in elevation 2 inches. The dotted triangles 1 2 3 in plan represent the section of the article on the line 2–3 in elevation: and the solid triangle $1^1$ $2^1$ $3^1$ in plan, the section on the line $2^1$ $3^1$ in elevation. Now connect the two sections in plan by drawing lines from 1 to $2^1$ and to $3^1$, from 2 to $2^1$ and to $1^1$, and from 3 to $1^1$ and to $3^1$. In a similar manner connect the points in elevation as shown. It now becomes necessary to obtain a triangle giving the true length of the lines connecting the corners of the triangle in plan, and as all of these lines are equal only one triangle is necessary. Therefore take the distance from

1 to $2^1$ in plan and place it on the line 3–2 extended in elevation, as shown from 2 to $1^\circ$, and draw a line from $1^\circ$ to $2^1$, which is the desired length.

For the pattern, proceed as is shown in Fig. 10. Take the distance of any one of the sides in the triangle, as 1–2 in Fig. 9, and place it on the horizontal line 1–2 in Fig. 10. Then using 1 and 2 as centers, with $1^\circ$ $2^1$ in elevation in Fig. 9 as radius, describe the arcs in Fig. 10 intersecting each other in $2^1$. Then 1 2 $2^1$ will be the pattern for one of the sides shown in plan in Fig. 9 by 1 2 $2^1$. Proceed in this manner in Fig. 10 as shown by the small arcs; or a tracing may be taken of the one side 1 2 $2^1$, and traced as shown until six sides are obtained, which will be the full pattern and which is numbered to correspond to the numbers in plan.

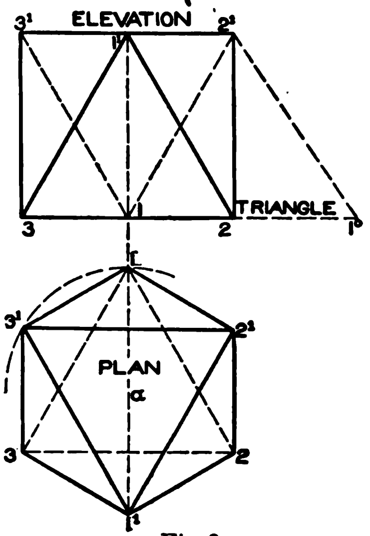


Fig. 9.

In Figs. 11, 12, and 13 are shown the methods used in developing a scalene cone. The method of obtaining the development of any scalene cone, even though its base is a perfect circle, is governed by the same principle as employed in the last problem on triangu-

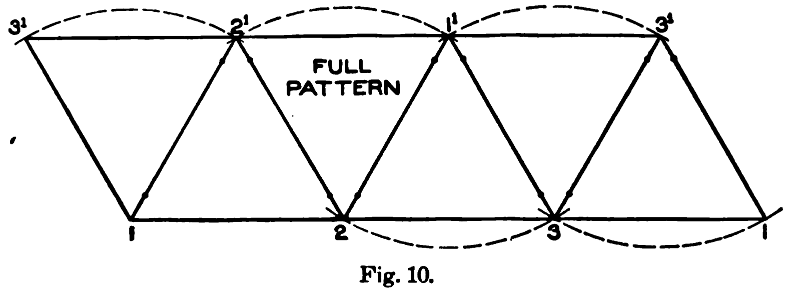


Fig. 10.

lation It is well to remember that any section of a scalene cone drawn parallel to its base will have the same shape (differing of course in size) as the base. This is equally true of articles whose bases are in the shape of a square, rectangle, hexagon, octagon, or any other polygon. What has just been explained will be proven in connection with Fig. 11, in which A B C represents a side elevation of a scalene cone, whose plan is shown by 1 4' 7 4 C'. Draw any horizontal line, as A D, on which set off the distances

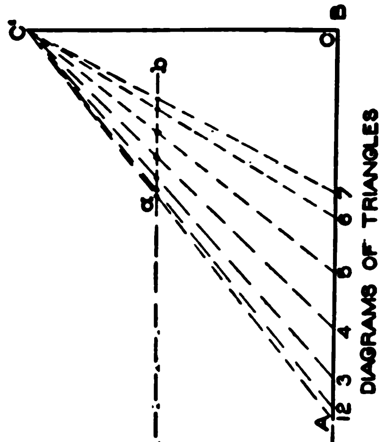



Fig. 12.

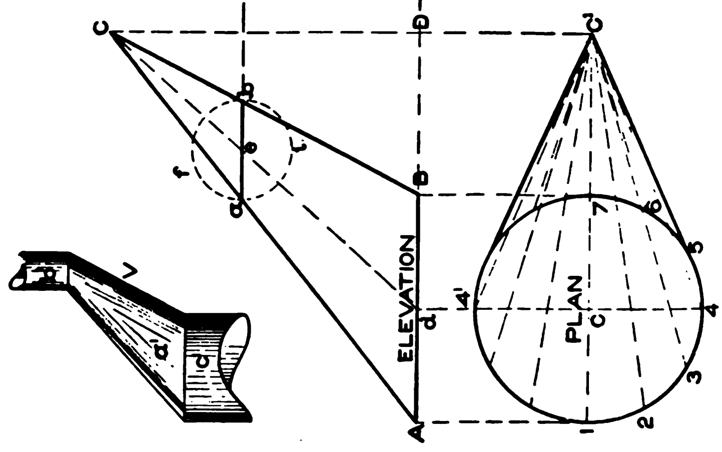



Fig. 11.

A B equal to 3 inches and B D equal to 2½ inches, and the vertical height D C equal to 4½ inches. Draw lines from B and A to C, which completes the elevation. In its proper position below the line A B, draw the ... R as 1 4 7 4' struck from the center C. ... line C C', and intersect it by a vertical line drawn from the apex C in elevation, thus obtaining the apex $C^1$ in plan. Draw lines from 4 and $4^1$ to $C^1$, which completes the plan.

As both halves of the scalene cone are symmetrical, it is necessary only to divide the half plan 1 4 7 into a number of equal spaces as shown by the small figures 1 to 7, and from points thus obtained draw radial lines to the apex $C^1$. Then these lines in plan will represent the bases of triangles which will be constructed, whose altitudes are all equal to D C in elevation. Therefore in Fig. 12 draw any horizontal line, as A B, and from any point, as C, erect the perpendicular line C $C^1$ equal in height to D C in Fig. 11. Now from $C^1$ in plan take the various lengths of the lines 1 to 7 and place them on the line A B in Fig. 12, measuring in every instance from the point C, thus obtaining the intersections 1 to 7, from which lines are drawn to the apex $C^1$. Then these lines will represent the true lengths of similarly numbered lines in plan in Fig. 11.

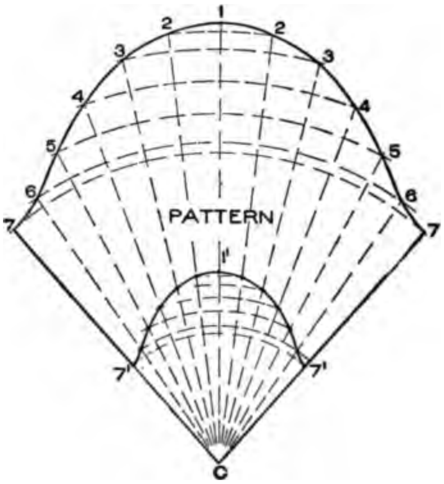


Fig. 13.

For the pattern proceed as is shown in Fig. 13. With C as center and radii equal to $C^1$ 7, 6, 5, 4, etc., in Fig. 12, describe the arcs 7–7, 6–6, 5–5, 4–4, etc., in Fig. 13 as shown. Now assuming that the seam is to come on the short side of the cone, as C B in Fig. 11, set the dividers equal to one of the equal spaces in the plan; and starting on the arc 7–7 in Fig. 13, step from arc 7 to arc 6, to arcs 5, 4, 3, 2, and 1, and then continue to arcs 2, 3, etc., up to 7. Trace a line through these intersections as shown by 7–1–7, and draw lines from 7 and 7 to C, which completes the pattern.

Now to prove that any section of an oblique or scalene cone cut parallel to its base, has a similar shape to its base (differing in size), draw any line as *a b* in Fig. 11 parallel to A B. From C in plan erect a vertical line intersecting the base line A B at *d*, from which draw a line to the apex C, cutting the line *a b* at *e*. Then the distances *e a* and *e b* will be equal; and using *e* as a center and *e b* as radius, describe the circle *a f b i*, which is the true section on *a b*. Then *a b* B A will be the frustum of a scalene cone. Extend the line *a b* parallel to A D, cutting the diagram of triangles in Fig. 12 from *a* to *b*. Then with radii equal to the distances from $C^1$ to the various intersections on the line *a b*, and using C in Fig. 13 as center, intersect similarly numbered radial lines drawn from 7 to 1 to 7 to the apex C. A line traced as shown from 7′ to 1′ to 7′ will be the desired cut, and 7-7-7′-7′ will be the pattern for the frustum. The practical use of this method is shown in diagram V in Fig. 11; *a′* is the frustum of the oblique cone, on the ends of which are connected round pipes *b′* and *c′*.

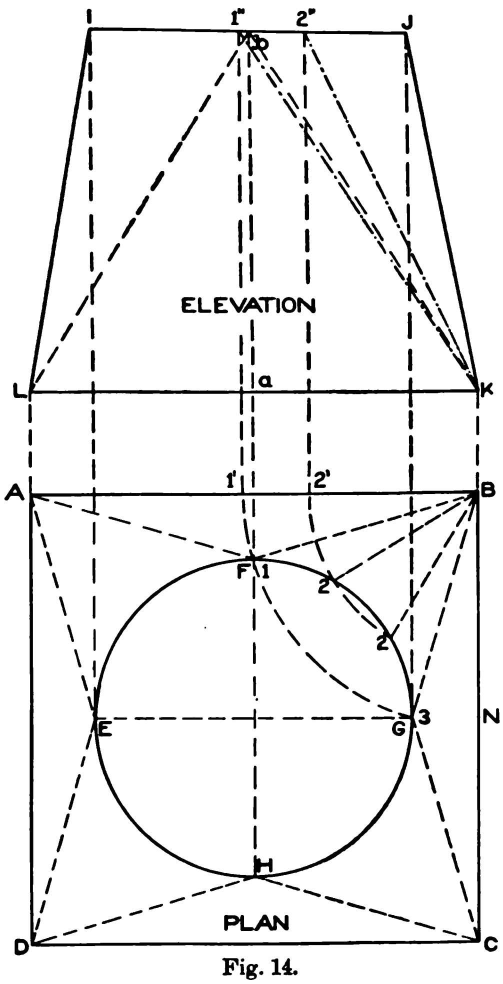


Fig. 14.

It is shown in Fig. 14 how in an irregular solid whose base is square and top is round, both top and bottom on horizontal planes are developed. The corners in plan F B G, G C H, H D E and E A F should be considered as sections of scalene cones. Proceed by drawing the plan A B C D 3½ inches square, which represents the plan of the base of the article; and the circle E F G H $2\frac{1}{2}$ inches in diameter, which shows the plan of the top of the article; the vertical height to be 3 inches, shown from *a* to *b*. As the circle is in the center of the square, making the four corners symmetrical, it is necessary only to divide the one-quarter circle into a number of equal parts as shown by the small figures 1, 2, 2, 3, from which draw lines to the apex B. Complete the elevation as shown by I J K L. Now using B as center, and radii equal to B 1 and B 2 in plan, describe arcs intersecting A B at 1′ and 2′ as shown. From these points erect perpendiculars intersecting the top of the article I J

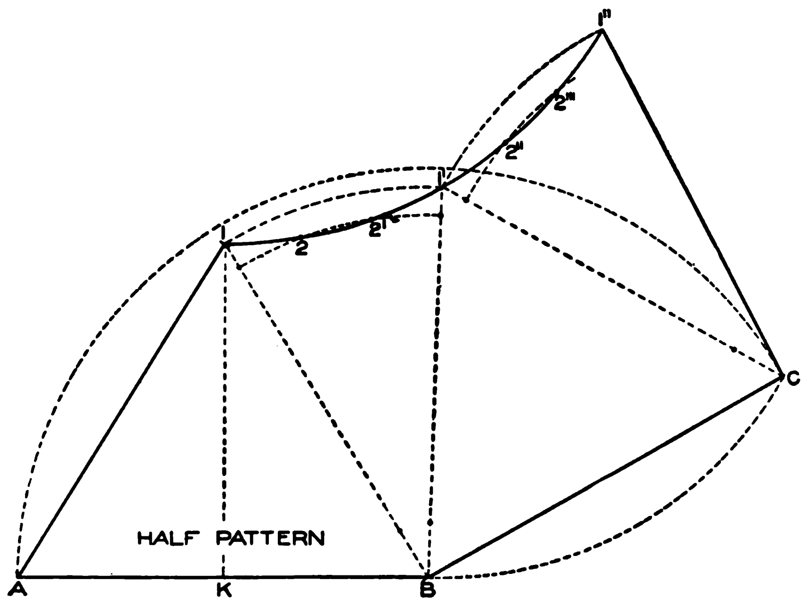



Fig. 15.

in elevation at 1″ and 2″, from which draw lines to K. Then K 1″ and K 2″ will be the true lengths of the lines shown in plan by B 1 and B 2 respectively on the finished article.

For the half pattern proceed as follows: In Fig. 15 draw any horizontal line, as A B, equal in length to A B in plan in Fig. 14. Now with K 1″ as radius and A and B in Fig. 15 as centers, describe arcs intersecting each other at 1 From 1 drop a vertical line intersecting A B at K. Then 1 K should equal J K in elevation in Fig. 14, which represents the true length through G N in plan.

Now with radii equal to K 1″ and K 2″ in elevation, and with B in Fig. 15 as center, describe the arcs 1–1′ and 2–2′. Now set the dividers equal to one of the spaces in G F in plan in Fig. 14; and starting at 1 in Fig. 15, step off arcs having similar numbers as shown by 1, 2, 2′, 1′. Now using 1 B as radius, and 1′ as center, describe the arc B C, and intersect it by an arc struck from B as center and with B A as radius, as shown at C. Take a tracing of 1 B 1′ and place it as shown by 1′ C 1″. Now connect the various intersections by drawing lines from 1 to A to B to C to 1″ to 1′ to 1, which completes the half pattern. The triangular pieces 1 A B or 1′ B C will represent the flat sides of the article shown in plan by 1 A B or 3 B C respectively in Fig. 14; and the cone patterns 1–1′ B and 1′–1″ C in Fig. 15, the sections of the scalene cones 1–3–B and H–G–C respectively in plan in Fig. 14. This same rule is applicable whether the top opening of the article is placed exactly in the center of the base or at one side or corner. Various problems of this nature will arise in Practical Workshop Problems; and if the principles of this last problem are thoroughly understood, these will be easily mastered.

**Approximate Developments.** In developing the blanks or patterns for sheet-metal work which requires that the metal be hammered or raised by hand, or passed between male and female dies in foot or power presses, circular rolls, or hammering machines, the blanks or patterns are developed by the approximate method, because no accurate pattern can be obtained. In all raised or pressed work in sheet metal, more depends upon the skill that the workman has with the hammer, than on the patterns, which are but approximate at their best. While this is true, it is equally true that if the workman understands the scientific rule for obtaining these approximate patterns a vast amount of time and labor can be saved in bringing the metal to its proper profile. If the true rule for averaging the various shapes and profiles in circular work is not understood, the result is that the blank has either too little or too great a flare and will not form to its proper profile and curve. Before proceeding to describe the approximate development methods, attention is called to the governing principle underlying all such operations. We have previously shown how the patterns are developed for simple flaring ware; in other words, how to develop the frustum of a cone. The patterns for curved or any other form of circular or hammered work are produced upon the same principle. The first illustration of that principle is shown in Fig. 16, in which A B C D represents a sphere 3 inches in diameter composed of six horizontal sections, struck from the center *a*.

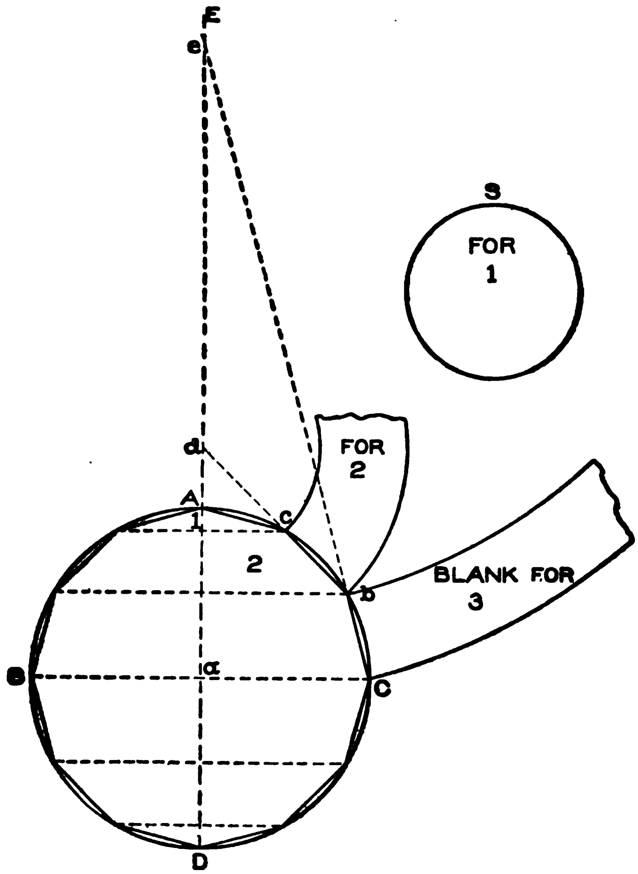



Fig. 16.

Divide the quarter circle A C into as many parts as there are sections required in the half sphere (in this case three), and draw horizontal lines through the ball as shown. The various radii for the patterns are then obtained by drawing lines through C *b*, *b c*, and *c* A. Thus C *b* extended meets the center line E D at *e*, which is the center for striking the blank for number 3, using the radii *e b* and *e* C. In similar manner draw a line from *b* to *c*, extending it until it meets E D at *d*. Then *d c* and *d b* will be the radii for blank number 2, while A *c* is the radius for blank 1 shown at S. The lengths of the pattern pieces are determined in the same manner as would be the case with an ordinary flaring pan in producing the patterns for tin ware, and will be explained

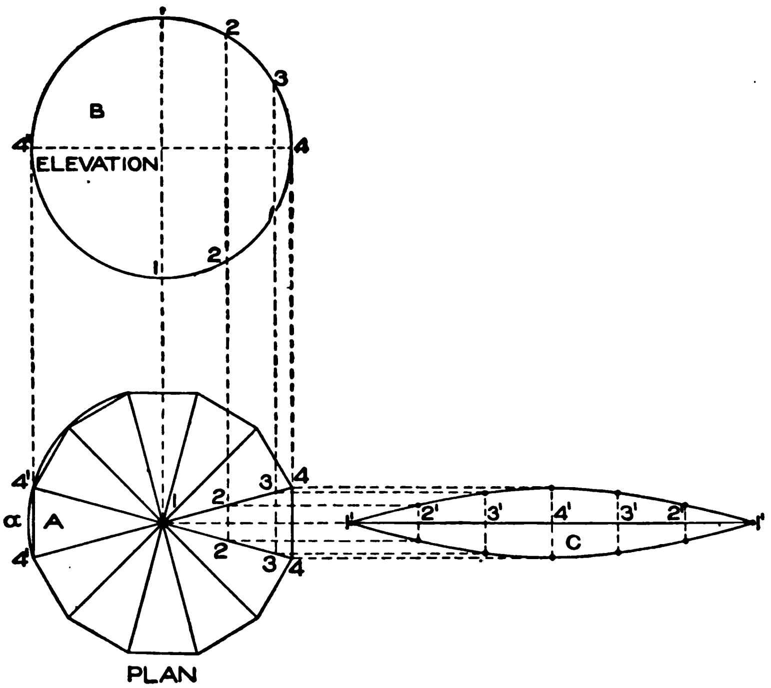



Fig. 17.

thoroughly in the Practical Workshop Problems which will shortly follow.

In Fig. 17 is shown another elevation of a sphere composed of twelve vertical sections as shown in plan view. While the method used for obtaining the pattern is by means of parallel lines, and would be strictly accurate if the sections in plan remained straight as from 4 to 4, the pattern becomes approximate as soon as we start to raise it by means of machine or hammer to conform to the profile B in elevation, because the distance along the curve *a* from 4′ to 4′

in plan is greater than a straight distance from 4 to 4. The pattern by this method is obtained as follows: Let B represent the elevation of the sphere, and A the plan of the same, which is divided into as many sides as the sphere is to have vertical sections, in this case 12, being careful that the two opposite sides 4–4 and 4′ 4′ in plan run parallel to the center line as shown. Make the diameter of the sphere 4–4′ 3 inches. Divide the half elevation into an equal number of spaces as shown from 1 to 4 to 1, and from these points drop lines at right angles to 4–4′ intersecting the miter lines 1–4 in plan as shown. Now draw any horizontal line, as 1′–1′, upon which place the stretchout of 1–4–1 in elevation as shown by 1′–4′–1′ on the line 1′–1′ in C. Through these points draw lines at right angles to 1′–1′, which intersect by lines drawn from similarly numbered intersections on the miter lines 1–4 in plan, at right angles to 4–4. A line traced through points thus obtained as shown by C will be the desired pattern.

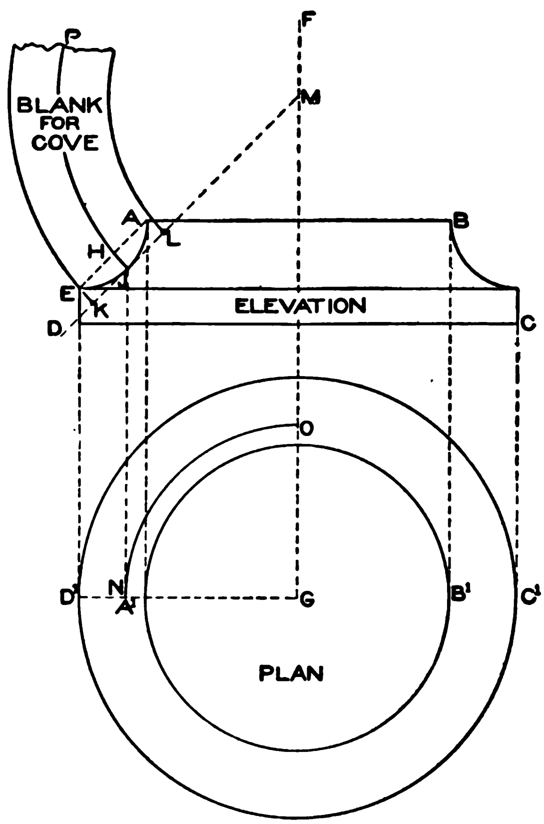



Fig. 18.

In Fig. 18 is shown the principle used in obtaining the radii with which to develop the blank for a curved or circular mould when it is to be hammered by hand. In this connection, only the principle employed will be shown, leaving the full development and also the development for patterns which are to be raised by hand

and hammered by machine, to be explained in problems which will follow in Practical Workshop Problems. Draw this problem double the size shown. First draw the elevation A B C D, and through the elevation draw the center line F G. Then using G as a center, draw the circles $A^1$ $B^1$ and $C^1$ $D^1$ representing respectively the horizontal projections of A B and C D in elevation. Now draw a line from A to E in elevation, connecting the corners of the cove as shown. Bisect A E and obtain the point H, from which at right angles to A E draw a line intersecting the cove at J. Through J parallel to A E draw a line intersecting the center line F G at M. Take the stretchout from J to A and from J to E and place it on the line J M as shown respectively from J to L and from J to K. Then will M L and M K be the radii with which to strike the pattern or blank for the cove. From J drop a vertical line intersecting the line $D^1$ G in plan at N. Then with G as center strike the quarter circle N O. Now using M as center and M J as radius, strike the arc J P. Then on this arc, starting from J, lay off 4 times the stretchout of N O in plan for the full pattern. It should be understood that when stretching the cove A E, the point J remains stationary and the metal from J to L and from J to K is hammered respectively toward J A and J E. For this reason is the stretchout obtained from the point J.

## PRACTICAL WORKSHOP PROBLEMS.

In presenting the 32 problems which follow on sheet-metal work, practical problems have been selected such as would arise in every-day shop practice.

In this connection we wish to impress upon the student the necessity of working out each and every one of the 32 problems. Models should be made from stiff cardboard, or, if agreeable to the proprietor of the shop, the patterns can be developed at home, then cut out of scrap metal in the shop during lunch hour, and proven in this way.

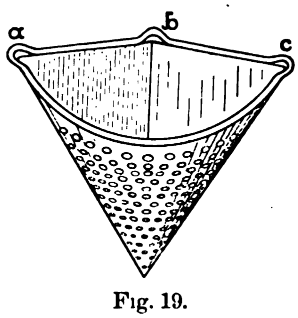


Fig. 19.

Our first problem is shown in Fig. 19, and is known as a sink drainer. It is often the case that the trap under the kitchen sink is choked or blocked, owing to a collection of refuse matter. To avoid this a sink drainer is used, and is fastened in position through the wire loops *a*, *b* and *c*. The refuse matter is poured into the drainer, from which it is easily removed after the fluid has passed through the perforations. These drainers may be made of tin or of black or galvanized iron, but where a good job is wanted 16-ounce copper should be used. To obtain the pattern for any sized drainer, proceed as follows: First draw the plan of the drainer A B C in Fig. 20, making A B and B C each two inches and forming a right angle. Then using B as center and A B as radius, draw the arc A C. In its proper position above the plan construct the side elevation, making E D 2 inches high, and draw the line F D. Then will F E D be the side elevation. Divide the arc A C into equal spaces as shown by the small figures 1 to 5. For the pattern use F D as radius, and with D in Fig. 21 as center strike the arc 1 5. From 1 draw a line to D and step off on 1–5 the same number of spaces as contained in A C in plan in Fig. 20, as shown by similar figures in Fig. 21. Draw a line from 5 to D. Then will 1–5–D be the pattern for the front of the strainer, in which perforations should be punched as shown. To join the sides of this pattern, use 1 and 5 as centers, and with either F E or A B in Fig. 20 as radius, describe the arcs E and $E^1$ in Fig. 21. Now using D as center and D E in Fig. 20 as radius, intersect the arcs E and $E^1$ as shown in Fig. 21. Draw lines from 1 to $E^1$ to D to E to 5, which completes the pattern, to which edges must be allowed for wiring at the top and seaming at the back.

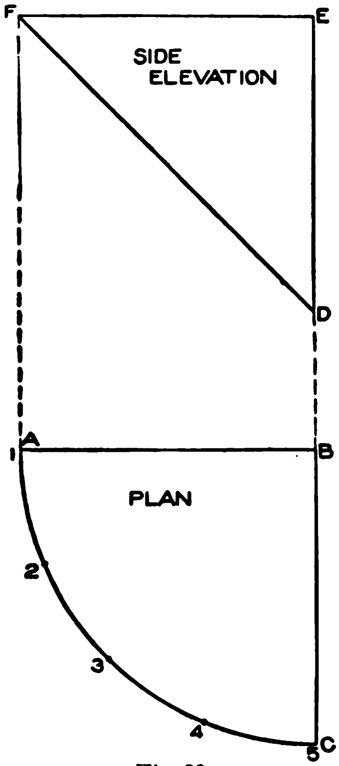


Fig. 20.

When joining a faucet or stop cock to a sheet-metal tank it is usual to strengthen the joint by means of a conical "boss," which is indicated by A in Fig. 22. In this problem the cone method is employed, using principles similar to those used in developing a frustum of a cone intersected by any line. Therefore in Fig. 23 let

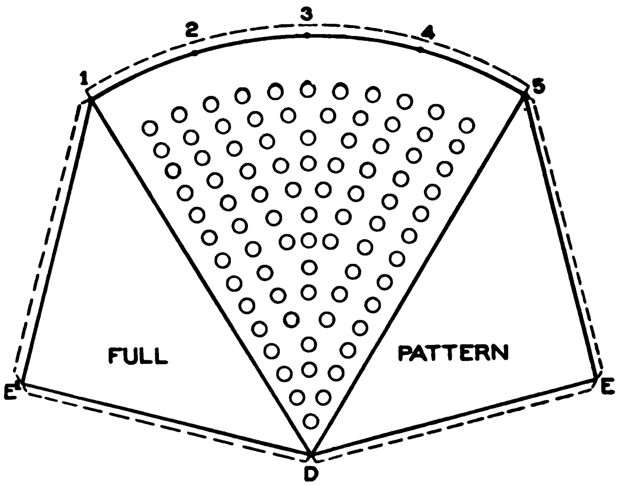



Fig. 21.

A B represent the part plan of the tank, C portion of the faucet extending back to the tank line, and F G H I the conical "boss" to fit around a faucet. When drawing this problem make the radius of the tank D A equal to 3½ inches, and from D draw the vertical line D E. Make the distance from G to H equal to 2¾ inches, the diameter of the faucet F I 1¼ inches and the vertical height K C 1½ inches. Draw a line from G to H intersecting the center line D E at K. Then using K as center describe the half section G J H as shown. Divide J H into equal parts shown from 1 to 4, from

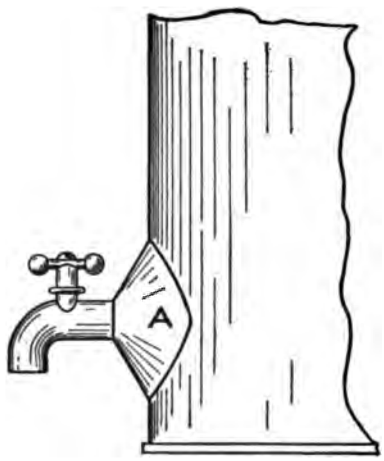



Fig. 22.

which drop vertical lines intersecting the line G H as shown, from which draw radial lines to the apex E cutting the plan line of the tank A B as shown. From these intersections draw horizontal lines intersecting the side of the cone H I at 1, 2′, 3′, and 4′. Now use E as center, and with radius equal to E 1 describe the

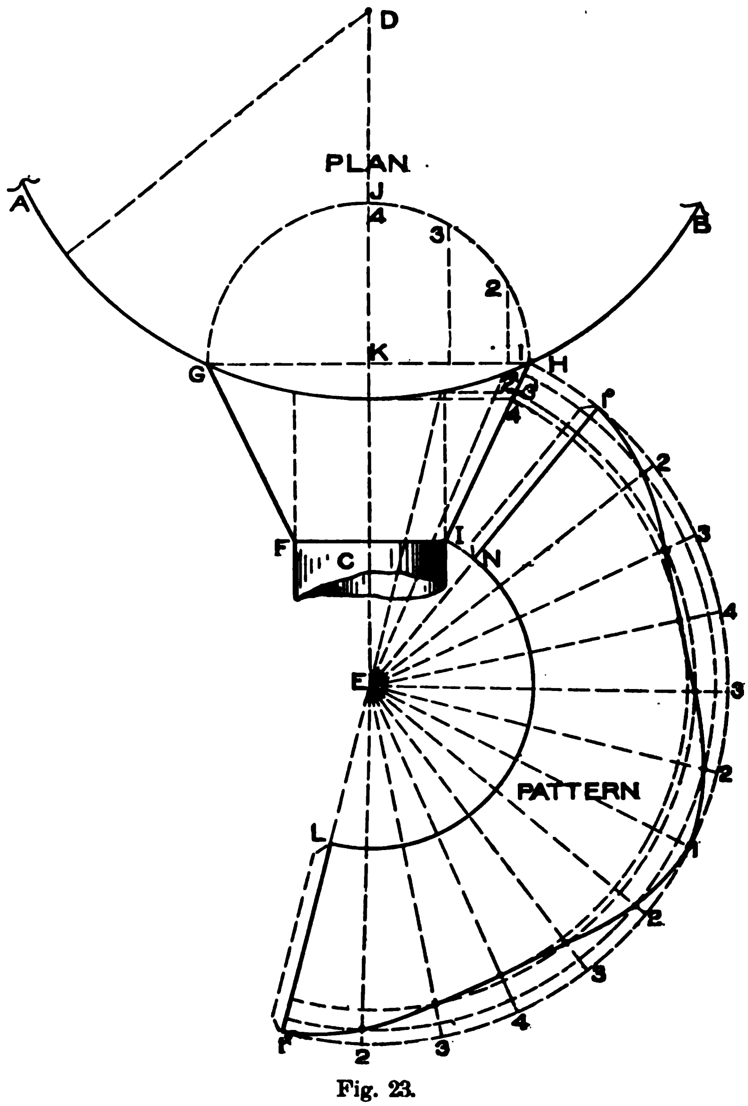



Fig. 23.

arc 1°–1ˣ as shown. Draw a line from 1° to E, and starting from 1° set off on 1°–1ˣ four times the number of spaces contained in

J H in plan, as shown by similar numbers on 1° 1ˣ. Draw a line from 1ˣ to E, and with E I as radius describe the arc N L intersecting the radial lines 1° E and 1ˣ E at N and L respectively. From the various numbers on the arc 1° 1ˣ draw radial lines to the apex E; and using E as center and with radii equal to E 4′, E 3′, and E 2′, draw arcs intersecting similarly numbered radial lines as shown. Trace a line through points thus obtained; then will N 1° 1 1ˣ L be the pattern for the "boss."

In Fig. 24 is shown what is known as a hip bath. In drawing out the problem for practice the student should remember that it is similar to the preceding one, the only difference being in the outline of the cone. Make the top of the cone I B in Fig. 25 equal to 3¼ inches, the bottom C D 1¾ inches, the vertical height from K to 5′ 2⅛ inches, the diameter of the foot E F 2¼ inches, and the vertical height 5′-5″ ¼-inch. Through the center of the cone draw the center line K L, and at pleasure draw the outline of the bath as shown by A J B. It is immaterial of what outline this may be, the principles that follow being applicable to any case. Thus, in the side elevation, extend the lines B C and A D until they intersect the center line at L. In similar manner extend the sides of the foot piece E D and F C until they intersect the center line at R. Now with 5′ as center and with radius equal to 5′ D or 5′ C, describe the half section C H D, which divide into equal spaces as shown by the small figures 1 to 9. From the points of division erect vertical lines meeting the base line of the bath D C at points 1, 2′, 3′, etc., to 9. From the apex L and through these points draw radial lines intersecting the outline B J A, from which horizontal lines are drawn intersecting the side of the bath B C as shown from 1 to 9. For the pattern for the body use L as center, d with L C as radius draw the arc F L¹. Now starting at any as 1, set off on F L¹ twice the stretchout of D H C as shown ilar numbers on the arc F L¹. From the apex L and through nall figures draw radial lines, which intersect by arcs

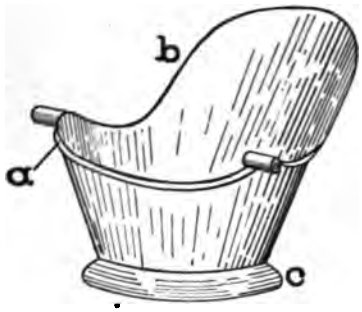


Fig. 24.

struck from L as center with radii equal to similarly numbered intersections on B C. Trace a line through points thus obtained, and $L^1$ M N P F will be the pattern for the body of the bath, to which laps should be added at the bottom and sides for seaming.

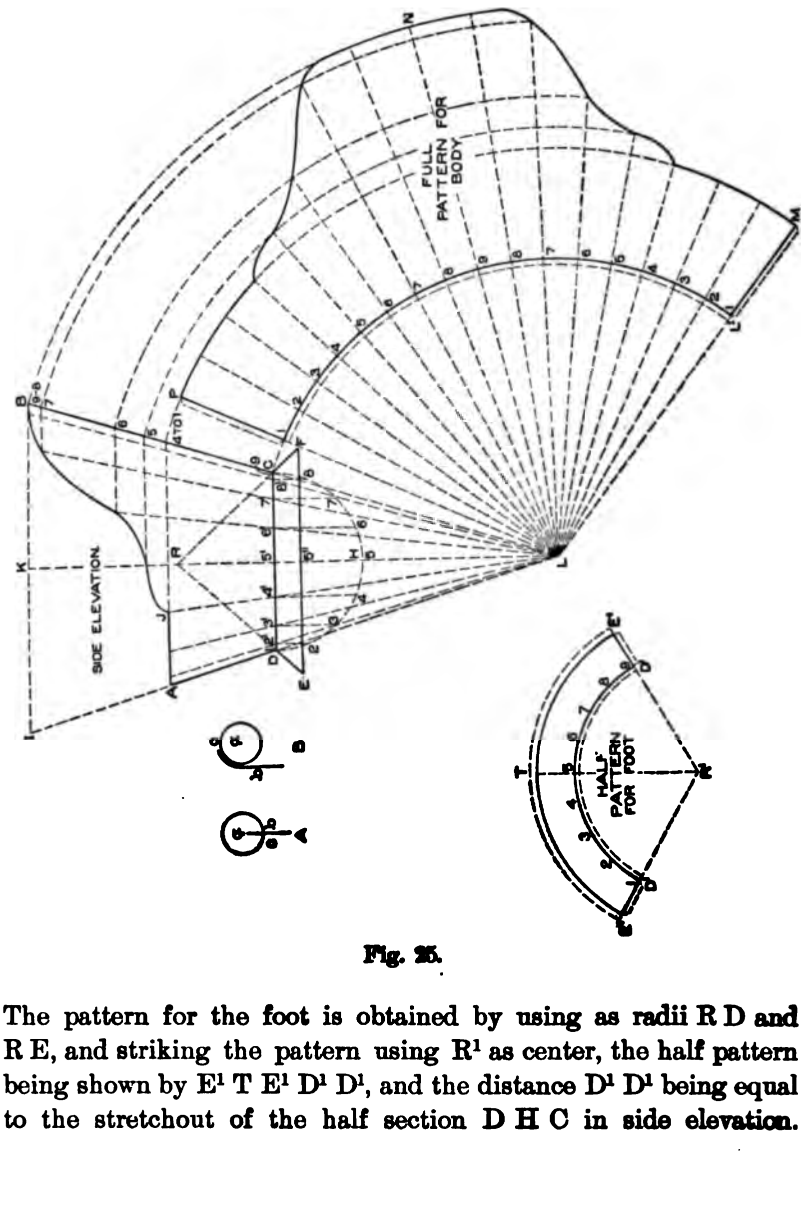



Fig. 25.

The pattern for the foot is obtained by using as radii R D and R E, and striking the pattern using $R^1$ as center, the half pattern being shown by $E^1$ T $E^1$ $D^1$ $D^1$, and the distance $D^1$ $D^1$ being equal to the stretchout of the half section D H C in side elevation.

It is usual to put a bead along the edges of the top of a bath as shown at *a* and *b* in Fig. 24. For this purpose tubing is sometimes used, made of brass, zinc, or copper and bent to the required shape; or zinc tubes may be rolled and soldered by hand, filled with heated white sand or hot rosin, and bent as needed. The tube or bead can be soldered to the body as shown in (A) in Fig. 25. Here *a* represents the bead, in which a slot is cut as *c*, and which is then slipped over the edge of the bath and soldered. Another method is shown in (B), in which the bath body *b* is flanged over the bead *a* and soldered clean and smooth at *c*, being then scraped and sandpapered to make a smooth joint. A wired edge is shown at *c* in Fig. 24, for which laps must be allowed as shown in Fig. 25 on the half pattern for foot.

In Fig. 26 is shown the perspective view of a bath tub; these tubs are usually made from IX tin or No. 24 galvanized iron. The bottom and side seams are locked and thoroughly soldered, while the top edge is wired with handles riveted in position as shown at A. The method used in developing these patterns will be the cone method and triangulation. In drawing this problem for practice (Fig. 27), first draw the center line W 8 in plan; and using *a* as center with a radius equal to 1½ inches draw the semicircle C–12 D. Now make the distance *a* to *b* 4 inches; and using *b* as center with a radius of 1⅝ inches draw the semicircle E–7–H. Draw lines from E to D and from C to H. D E 7 H C 12 D will be the plan of the bottom of the bath. In this case we assume that the flare between the top and bottom of the narrow end of the bath should be equal; therefore using *a* as center and with a radius equal to 1⅝ inches draw the semicircle A W B. At the upper end of the bath the flare will be unequal; therefore from *b* measure a distance on line W 8 of 1 inch and obtain *c*, which use as center, and with a radius equal to 2 inches describe the arc F 8 G. Draw lines from F to A and from B to G; and A F 8 G B W A will be the plan of the top of the bath. Now project the side elevation from the plan as shown by the dotted lines, making the slant height from I to R 2⅛ inches and from J to K 3⅛ inches; draw a line

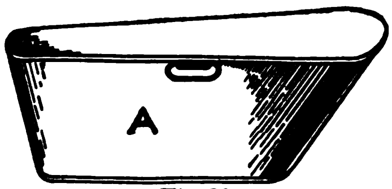


Fig. 26.

from K to R, and J K R I will be the side elevation of the bath tub. In constructing the bath in practice, seams are located at H G, F E,

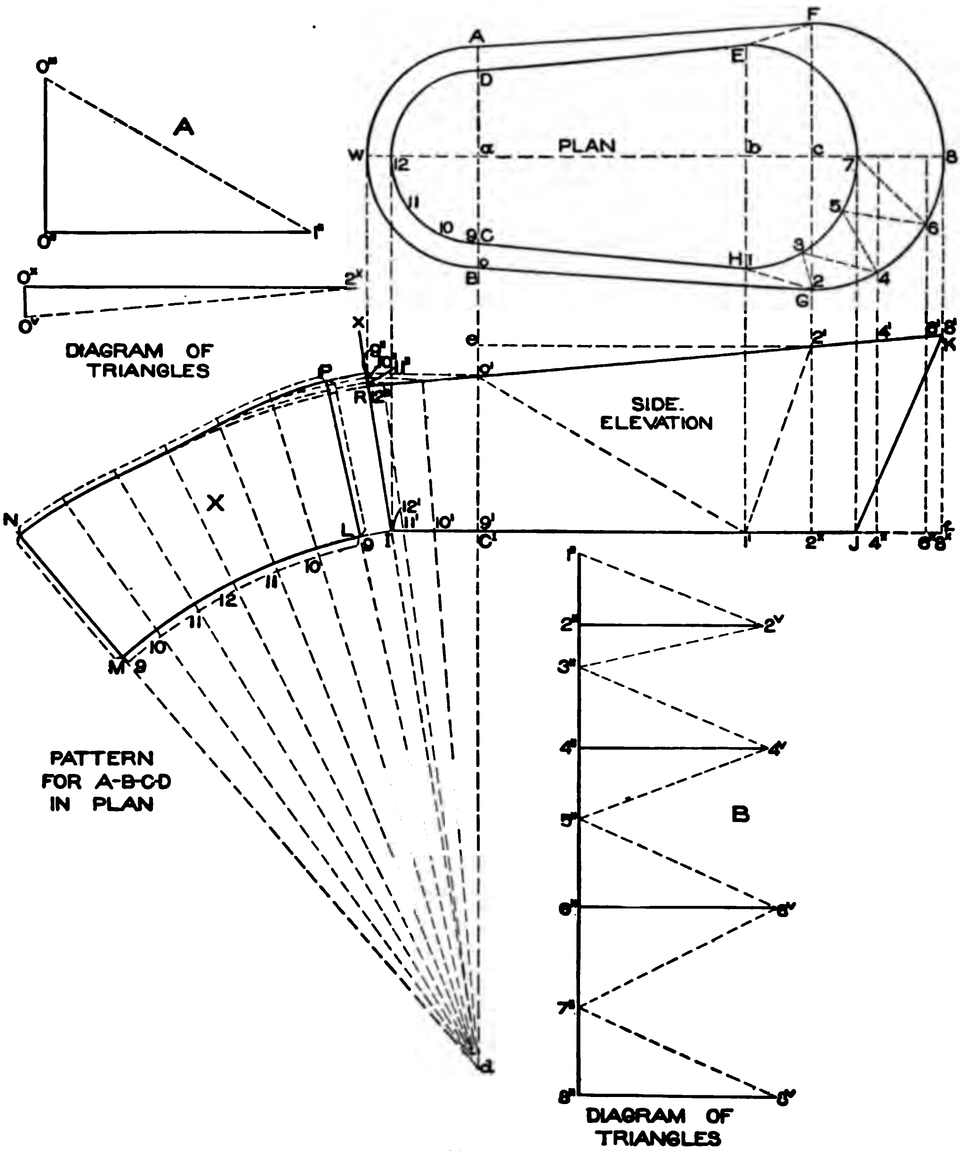



Fig. 27.

A D, and C B in plan, thus making the tub in four pieces

The lower end of the bath will be developed by the cone method as in the last two problems. From the center $a$ drop a line indefinitely as shown. Extend the side R I of the side elevation until it meets the center line $a\ d$ at $d$. Now divide the quarter circle 12–9 in plan into equal spaces as shown by the small figures 9, 10, 11, and 12, from which drop vertical lines (not shown) intersecting the bottom of the bath tub in elevation from 9′ to 12′. Then through these points from $d$ draw lines intersecting the top line of the bath R K as shown, from which draw horizontal lines intersecting the side I–R extended as I X at points 9″ to 12″. Then using $d$ as center and $d$ I as radius, describe the arc I M, upon which place the stretchout of D 12 C in plan, as shown by similarly numbered points on L M. Through these points from $d$ draw radial lines, which intersect by arcs drawn from similarly numbered intersections on I R extended, using $d$ as center. Trace a line as shown, and L M N P will be the pattern for the lower end of the tub A B C D in plan. Laps should be allowed for wiring and seaming.

As the patterns for the upper end and sides will be developed by triangulation, diagrams of triangles must first be obtained, for which proceed as follows: Divide both of the quarter circles H 7 and G 8 in plan into the same number of spaces as shown respectively from 1 to 7 and from 2 to 8. Connect these numbers by dotted lines as shown from 1 to 2, 2 to 3, 3 to 4, etc. From the various points 2, 4, 6, and 8 representing the top of the bath, drop lines meeting the base line J $f$ in elevation at $2^x$, $4^x$, $6^x$, and $8^x$, and cutting the top line of the bath at 2′, 4′, 6′, and 8′. Then will the dotted lines in plan represent the bases of the triangles, which will be constructed, whose altitudes are equal to the various heights in elevation. Take the various distances 1 to 2, 2 to 3, 3 to 4, 4 to 5, etc., in plan up to 8, and place them on the vertical line 1″–8″ in (B) as shown from 1″ to 2″, 2″ to 3″, 3″ to 4″, 4″ to 5″, etc., up to 8″. For example, to obtain the true length of the line 6–7 in plan, remembering that the points having even numbers represent the top line of the bath and those having uneven numbers the base line, draw at right angles to 1″–8″ in (B), from 6″, a line equal in height to $6^x$–6′ in elevation, and draw a line from $6^v$ to 7″ in (B), which is the length desired. For the true length of 6–5 in plan it is necessary only to take this distance place it from $6''$ to $5'$ in (B) and draw a line from $6^{v}$ to $5'$. In this way each altitude answers for two triangles. In plan draw a line from 1 to 0. Then will two more triangles be necessary, one on the line 1–0, and the other on B G or 0–2. From $2'$ in elevation draw a horizontal line, as $2'\ e$, intersecting the vertical line dropped from 0 at $e$. Now take the distances 0 1 and 0 2, and place them in (A) as shown by the horizontal lines $0'$–$1'$ and $0^{x}$–$2^{x}$ respectively. At right angles to both lines at either end draw the vertical lines $0'$–$0'''$ and $0^{x}$–$0^{v}$ equal in height respectively to $C^{1}\ 0'$ and $e\ 0'$ in elevation. Draw in (A) lines from $2^{x}$ to $0^{v}$ and from $1'$ to $0'''$, which are the desired lengths. Before proceeding with the pattern, a true section must be obtained on $2'$–$8'$ in side elevation. Take the various distances $2'$ to $8'$ and place them on the line $2'$–$8'$ in Fig. 28. At right angles to $2'$–$8'$ and through the small figures draw lines as shown. Now measuring in each and every instance from the center line in plan in Fig. 27, take the various distances to points 2, 4, and 6 and place them on similarly numbered lines in Fig. 28, measuring in each case on either side of the line $2'$–$8'$, thus obtaining the intersections 2–4–6. A line traced through these points will be the true section on $2'$–$8'$ in elevation in Fig. 27.

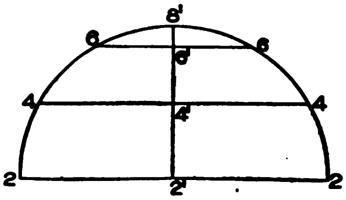


Fig. 28.

For the pattern for the upper end of the tub proceed as follows: Take the distance of $7'$–$8^{v}$ in (B) and place it on the vertical line 7–8 in Fig. 29. Then using 8 as center and with a radius equal to $8'$–6 in Fig. 28, describe the arc 6 in Fig. 29, which intersect by an arc struck from 7 as center and with $7'$–$6^{v}$ in (B) in Fig. 27 as radius. Then using 7–5 in plan as radius, and 7 in Fig. 29 as center, describe the arc 5, which intersect by an arc struck from 6 as center and with $6^{v}$–$5'$ in (B) in Fig. 27 as radius. Proceed in this manner, using alternately as radii first the divisions in Fig. 28, then the length of the slant lines in (B) in Fig. 27, the divisions on 7 H in plan, then again the slant lines in B, until the line 1–2 in Fig. 29 is obtained. Trace a line through points thus obtained, as shown by 2–8–7–1. Trace this opposite the line 8–7, as shown by 2′ 1′. Then will 2–8–2′–1′–7–1 be the desired pattern, to which laps must be allowed.

For the pattern for the side of the bath draw any line 9–1 in Fig. 30 equal to 9–1 in plan in Fig. 27. Now with a radius equal

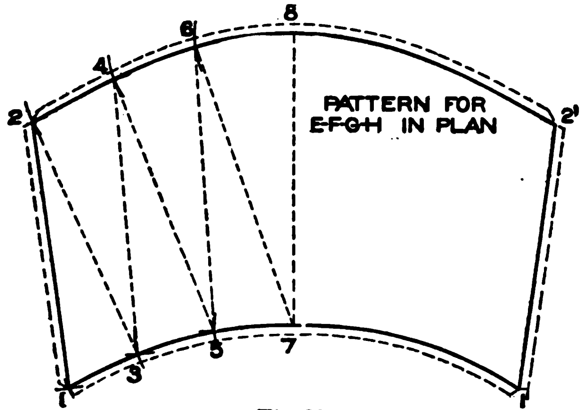



Fig. 29.

to 9–P in the pattern X and with 9 in Fig. 30 as a center, describe the arc 0, which intersect by an arc struck from 1 as center and with $1'$–$0'''$ in (A) in Fig. 27 as radius. Now taking a radius equal to $0^{v}$–$2^{x}$ in (A) with 0 in Fig. 30 as center, describe the arc 2, which intersect by an arc struck from 1 as center, and with 1–2 in Fig. 29 as radius. Draw lines from corner to corner in Fig. 30, which gives the desired pattern, to which laps are added for seaming and wiring.

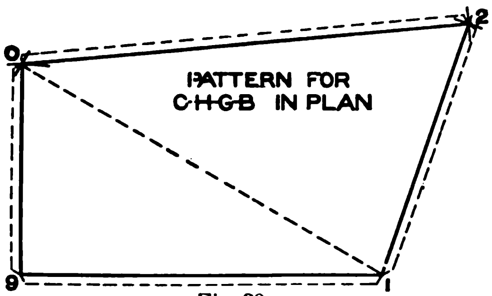



Fig. 30.

In Fig. 31 is shown a perspective view of a funnel strainer pail. These pails are usually made from IX bright tin, and the same principles as are used in the development of the pattern are applicable to similar forms, such as buckets, coal hods, chutes, etc. This problem presents an interesting study in triangulation, the principles of which have been explained in previous problems. First draw the center line C I in Fig. 32, at right angles to which draw H E and H F each equal to $1\frac{1}{4}$ inches. Make the vertical height H C $3\frac{1}{4}$ inches and C D 2 inches. Now make the vertical heights measuring from C G, to A, and to B respectively $1\frac{1}{4}$ inches, and $1\frac{1}{2}$ inches. Make the horizontal distance from C to G $2\frac{3}{4}$ inches, the diameter from G to A $1\frac{3}{8}$ inches, and from A to B $\frac{3}{4}$-inch, and draw a line from B to C. Connect points by lines; then will A B C D E F G be the side elevation of the pail. In its proper position below F E, with J as center, draw the plan K L M N. Also in its proper position draw the section on A G as O P R S. Now draw the rear elevation making $G^1$ U and $G^1$ V each equal to H E, and 1″ T and 1″–1′ each equal to C D. Project a line from B in side, intersecting the center line in rear at 4′. Then through the three points 1′ 4′ T draw the curve at pleasure, which in this case is struck from the center *a*. W Y X Z represents the opening on G A in side obtained as shown by the dotted lines but having no bearing on the patterns. Pails of this kind are usually made from two pieces, with seams at the sides, as in Fig. 31. The pattern then for the back shown by C D E H in side elevation in Fig. 32 will be obtained by the cone method, struck from the center I, the stretchout on $E^1$ $E^2$ in the pattern being obtained from the half plan. The pattern for C D E H is shown with lap and wire allowances by $D^1$ $D^2$ $E^2$ $E^1$ and needs no further explanation.

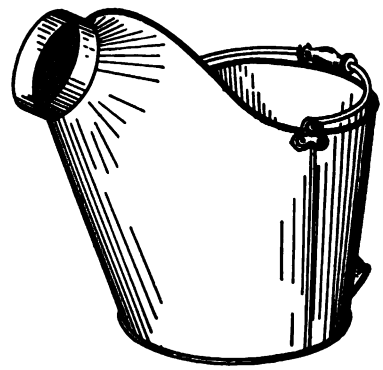


Fig. 31.

The front part of the pail shown by A B C H F G will be developed by triangulation, but before this can be done a true section must be obtained on B C, and a set of sections developed as follows: Divide one-half of 1′ 4′ T in rear elevation into equal parts as shown from 1′ to 4′, from which draw horizontal lines intersecting the line B C as shown. From these intersections lines are drawn at right angles to B C equal in length to similarly numbered lines in rear as 3′–3″, 2′–2″, and 1′–1″. Trace a line as shown, so that C 1‴ 2‴ 3‴ 4‴ will be the true half section on B C. To avoid a confusion of lines take a tracing of A B C H F G and place it as shown by similar letters in Fig. 33. Now take tracings of the half sections in Fig. 32, as H E D C, C 1‴ B, P O S, and the quarter plan N J M, and place them in Fig. 33 on similar lines on which they represent sections as shown respectively by H 9′ 8′ C, C 8 B, A 3 G, and F 9 H. Divide the half section

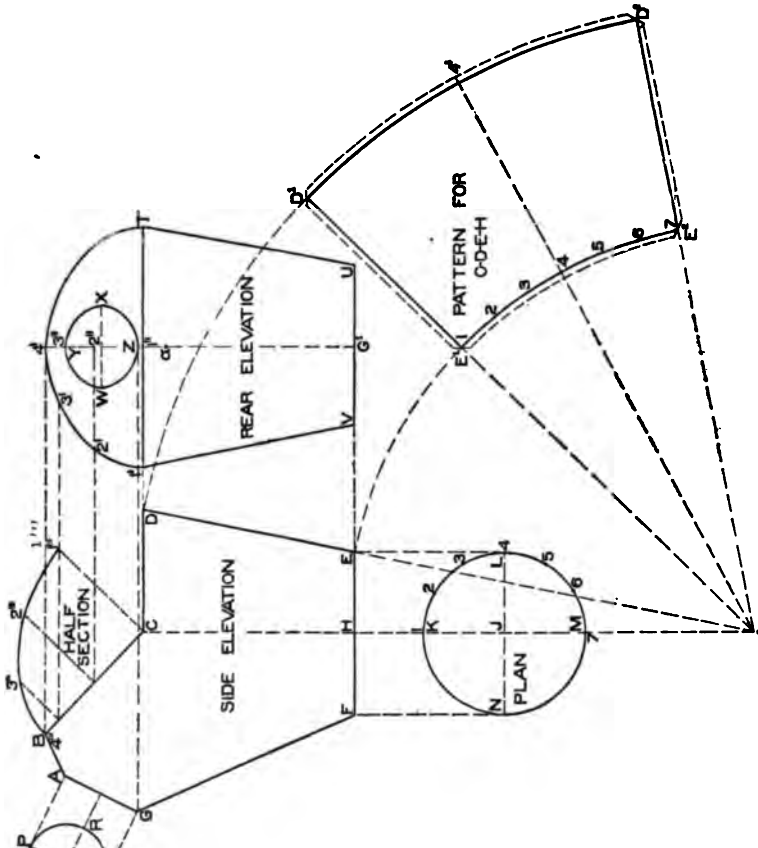


Fig. 32.

A 3 G into 6 equal parts as shown by the small figures 1 to 5. As this half section is divided into 6 parts, then must each of the sections B 8 C and F 9 H be divided into 3 parts as shown respectively from 6 to 8 and 9 to 11. As C 8′ and H 9′ are equal respectively to C 8 and H 9 they are numbered the same as shown.

Now at right angles to G A, B C, C H, and H F, and from the various intersections contained in the sections G 3 A, B 8 C, C 8′ 9′ H, and H 9 F, draw lines intersecting the base lines of the sections G A, B C, C H, and H F at points shown from 1′ to 11′. Now draw dotted lines from B to 5′ to 6′ to 4′ to 7′ to E to C, and then from H to E to 10′ to 2′, etc until all the points are

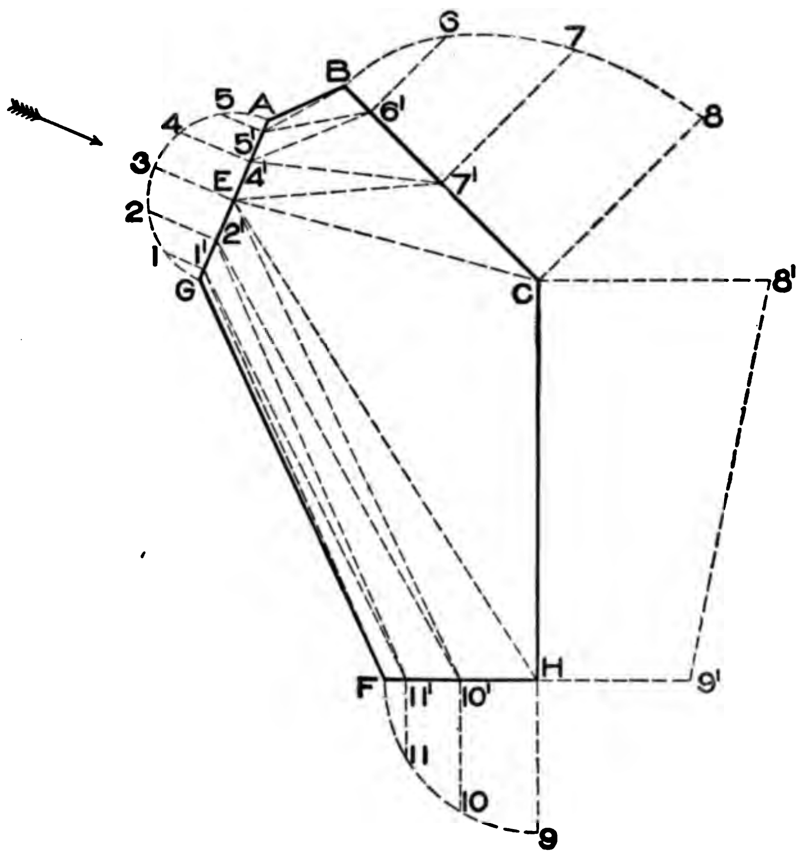



Fig. 33.

connected as shown. These dotted lines represent the bases of the sections whose altitudes are equal to similar numbers in the various sections.

In order that the student may thoroughly understand this method of triangulation as well as similar methods that will follow in other problems, the model in Fig. 34 has been prepared, which shows a perspective of Fig. 33 with the sections bent up in their proper positions. This view is taken on the arrow line in Fig. 33, the letters and figures in both views being similar. For the true sections on the dotted lines in C E A B in Fig. 33, take the lengths of the dotted lines C E, E 7′, 7′ 4′, etc., and place them on the horizontal line in Fig. 35 as shown by similar letters and figures. From these small figures, at right angles to the horizontal line, erect the vertical heights C 8, E 3, 7′ 7, etc., equal to similar

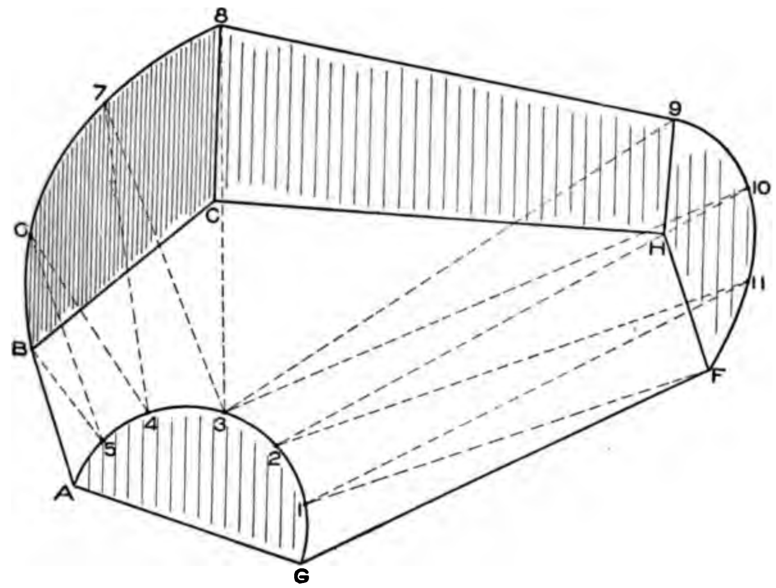



Fig. 34.

vertical heights in the sections in Fig. 33. Connect these points in Fig. 35 by dotted lines as shown, which are the desired true distances.

In Fig. 36 are shown the true sections on dotted lines in G E H F in Fig. 33, which are obtained in precisely the same manner, the only difference being that one section is placed inside of another in Fig. 36. For the pattern proceed as is shown in Fig. 37. Draw any vertical line as G F equal to G F in Fig. 33. With radius equal to G 1 and with G in Fig. 37 as center describe the arc 1, which intersect by an arc struck from F as center and with a radius equal to F 1 in Fig. 36. Now with F 11 in Fig. 33 as radius and F in Fig. 37 as center, describe the arc 11, which is intersected by an arc struck from 1 as center and with 1–11 in Fig 36 as radius. Proceed in this manner until the line 3–9 in Fig. 37 has been obtained. Then using 8′–9′ in Fig. 33 as radius and 9 in Fig. 37 as center, describe the arc 8, which is intersected by an arc struck from 3 as center and with 3–8 in Fig.

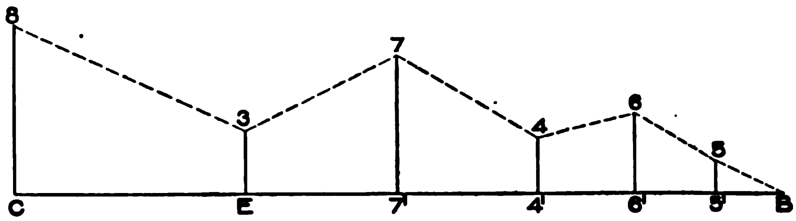



Fig. 35.

35 as radius. Now use alternately as radii, first the divisions in B 8 C in Fig. 33, then the length of the slant lines in Fig. 35, the divisions in E 3 A in Fig. 33, and again the distances in Fig. 35, until the line B A in Fig. 37 has been obtained, which is obtained from B A in Fig. 33. Trace a line through points thus obtained in Fig. 37 as shown by A B 8 9 F G A. Trace this half pattern opposite the line G F. Then will B A G $A^1$ $B^1$ $8^1$

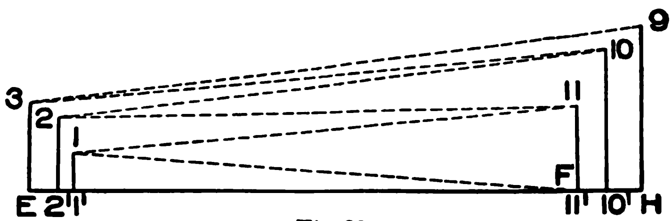



Fig. 36.

$9^1$ F 9 8 be the pattern for the front half of the pail. If for any reason the pattern is desired in one piece, then trace one-half of $D^1$ $D^2$ $E^2$ $E^1$ in Fig. 32 on either side of the pattern in Fig. 37 as shown by the dotted lines 8′ $D^1$ $E^1$ $9^1$ and 9 E D 8. Allow edges for wiring and seaming.

Fig 38 shows the method for obtaining the pattern for an Emerson ventilator shown in Fig. 39.

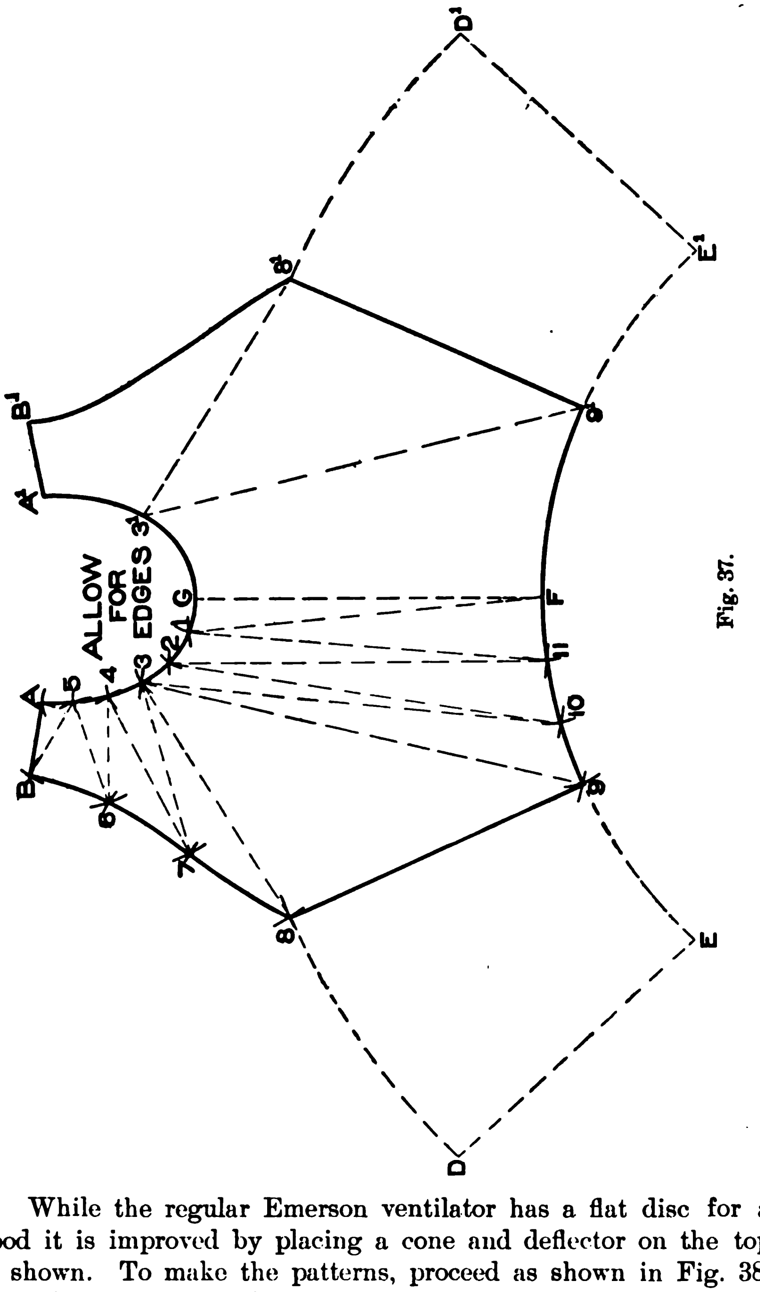



Fig. 37.

While the regular Emerson ventilator has a flat disc for a hood it is improved by placing a cone and deflector on the top as shown. To make the patterns, proceed as shown in Fig. 38. First draw the center line *a b*, on either side of which lay off

1½ inches, making the pipe A, 3 inches in diameter. The rule usually employed is to make the diameter of the lower flare and upper hood twice the diameter of the pipe. Therefore make the diameter of *s d* 6 inches. From *s* and *d*, draw a line at an angle of 45° to intersect the line of the pipe at *t* and *i*; this completes B. Measure 2 inches above the line *t i* and make *u m* the same diameter as *s d*. Draw the bevel of the deflector so that the apex will be ½ inch above the line *t i* and make the apex of the hood the same distance above *u m* as the lower apex is below it. Then draw lines as shown which complete C and D.

Fig. 39.

Now with *c* as a center and radii equal to *c e* and *c d* draw the quarter circles *e f* and *d h* respectively, which represent the one-

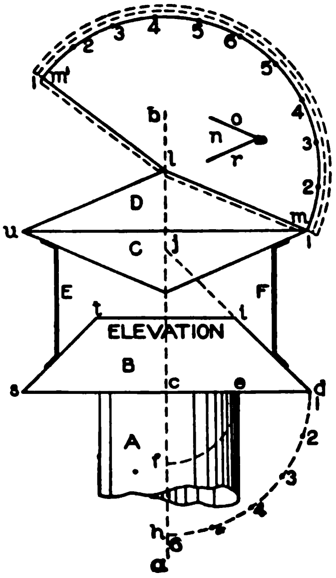



Fig. 38.

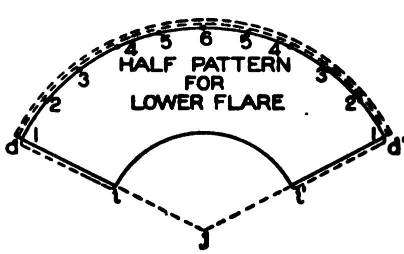



Fig. 40.

quarter pattern for the horizontal ring closing the bottom of the lower flare. For the pattern for the hood, use *l* as a center and *l m* as a radius. Now draw the arc *m m'*. Take the stretchout of the quarter circle 1 to 6 on *d h*, and place twice this amount on *m m'* as shown from 1–6–1. Draw a line from 1 to *l*. Then *m'* 6 *m l*, will be the half pattern for the hood. As the deflector has the same bevel as the hood, the hood pattern will also answer for the deflector.

When seaming the hood and deflector together as shown at *n*, the hood *o* is double-seamed to the deflector at *r*, which allows the water to pass over; for this reason allow a double edge on the pattern for the hood as shown, while on the deflector but a single edge is required. Edges should also be allowed on *e d h f*.

For the pattern for the lower flare, extend the line *d i* until it intersects the center line at *j*. Then with radii equal to *j i* and *j d* and with *j* in Fig. 40 as center describe the arcs *i i'* and *d d'*. On one side as *d* draw a line to *j*. Then set off on the arc *d d'*

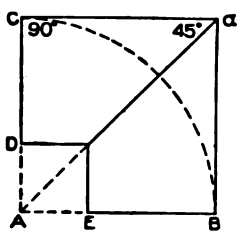



Fig. 41.

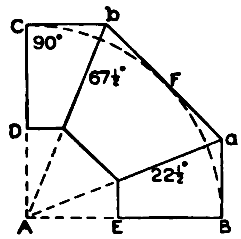



Fig. 42.

twice the number of spaces contained in *d h* in Fig. 38 as shown in Fig. 40. Draw a line from *d'* to *i'* and allow edges for seaming. Then *d d' i' i* will be the half pattern for the lower flare.

The braces or supports, E and F, Fig. 38, are usually made of galvanized band iron bolted or riveted to hood and pipe. The hood D must be water tight, or the water will leak into the deflector, from which it will drip from the apex inside the building.

**Elbows.** There is no other article in the sheet-metal worker's line, of which there are more made in practice than elbows. On this account rules will be given for constructing the rise of the miter line in elbows of any size or diameter, also for elbows whose sections are either oval, square or round, including tapering elbows Before taking up the method of obtaining the patterns, the rule will be given for obtaining the rise of the miter line for any size or number of pieces. No matter how many pieces an elbow has, they join together and form an angle of 90°. Thus when we speak of a two-pieced, three-pieced, four, five or six-pieced elbow, we understand that the right-angled elbow is made up of that number of pieces. Thus in Fig. 41 is shown a two-pieced elbow placed in the quadrant C B, which equals 90° and makes C A B a right angle. From A draw the miter line A *a* at an angle of 45° to the base line A B. Then parallel to A B and A C and tangent to the quadrant at C and B draw lines to intersect the miter line, as shown. Knowing the diameter of the pipe as C D or E B draw lines parallel to the arms of the pipe, as shown. Then C B E D will be a two-pieced elbow, whose miter line is an angle of 45°.

In a similar manner draw the quadrant B C, Fig. 42, in which it is desired to draw a three-pieced elbow. Now follow this simple

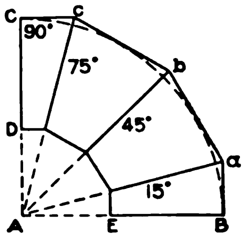



Fig. 43.

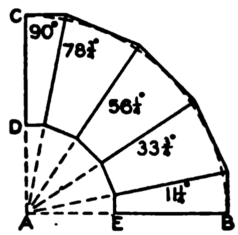



Fig. 44.

rule, which is applicable for any number of pieces: Let the top piece of the elbow represent 1, also the lower piece 1, and for every piece between the top and bottom add 2. Thus in a three-pieced elbow:

| | |
|---|---|
| Top piece equals | 1 |
| Bottom piece equals | 1 |
| One piece between | 2 |
| Total equals | 4 |

Now divide the quadrant of 90° by 4 which leaves $22\frac{1}{2}^\circ$. As one piece equals $22\frac{1}{2}^\circ$, draw the lower miter line A *a* at that angle to the base line A B. Then as the middle piece represents two by the above rule and equals 45°, add 45 to $22\frac{1}{2}$ and draw the second miter line A *b*, at an angle of $67\frac{1}{2}^\circ$ to the base line A B. Now tangent to the quadrant at C and B draw the vertical and horizontal lines shown, until they intersect the miter lines, from which intersections draw the middle line, which will be tangent to the quadrant at F. C D and B E show the diameters of the pipe, which are drawn parallel to the lines of the elbow shown.

Fig. 43 shows a four-pieced elbow, to which the same rule is applied. Thus the top and bottom piece equals 2 and the two middle pieces equal 4; total 6. Now divide the quadrant of 90° by 6. $\frac{90}{6} = 15$. Then the first miter line A *a* will equal 15°, the second A *b* 45°, the third A *c* 75°, and the vertical line A C 90°.

The last example is shown in Fig. 44, which shows a five-pieced elbow, in which the top and bottom pieces equal 2, the 3 middle pieces 6; total 8. Divide 90 by 8. $\frac{90}{8} = 11\frac{1}{4}$. Then the first miter line will equal $11\frac{1}{4}$°, the second $33\frac{3}{4}$°, the third $56\frac{1}{4}$°, and the fourth $78\frac{3}{4}$°. By using this method an elbow having any number of pieces may be laid out. When drawing these miter lines it is well to use the protractor shown in Fig. 45, which illustrates how to lay out a three-pieced elbow. From the center point A of the protractor draw lines through $22\frac{1}{2}$°, and $67\frac{1}{2}$°. Now set off A *a*, and the diameter of the pipe *a b*. Draw vertical lines from *a* and *b* to the miter line at *c* and *d*. Lay off similar distances from A to *a′* to *b′* and draw horizontal lines intersecting the $67\frac{1}{2}$° miter line at *c′* and *d′*. Then draw the lines *d d′* and *c c′* to complete the elbow. In practice, however, it is not necessary to draw out the entire view of the elbow; all that is required is the first miter line, as will be explained in the following problems.

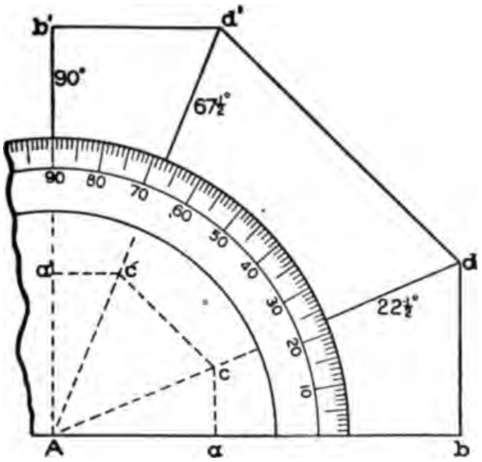


Fig. 45.

**EXERCISES FOR PRACTICE.**

1. Make the diameter of the pipe 1$\frac{3}{4}$ inches and the distances from A to E 1$\frac{1}{2}$ inches in Figs. 41 to 44 inclusive.

To obtain the pattern for any elbow, using but the first miter

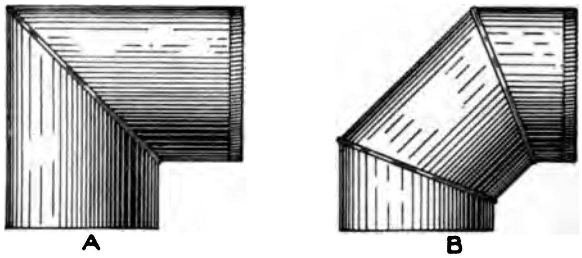



Fig. 46.

line, proceed as follows: In Fig. 46 let A and B represent respectively a two- and three-pieced elbow for which patterns are desired. First draw a section of the elbow as shown at A in Fig. 47 which

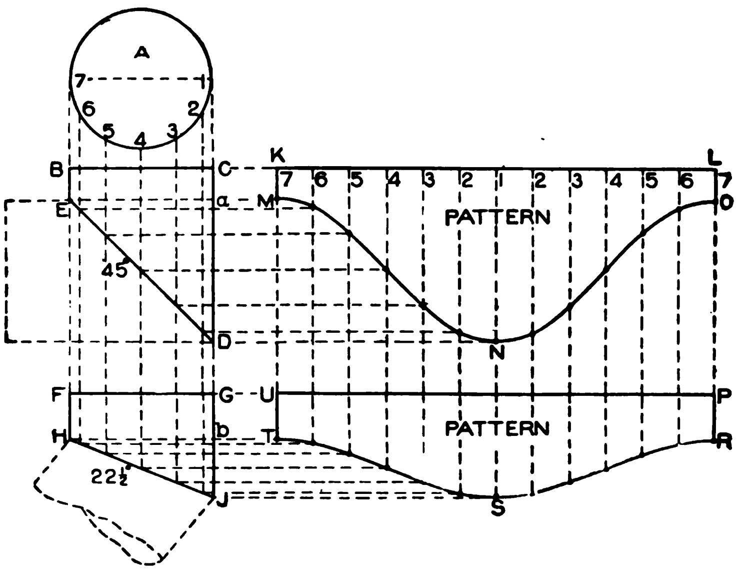



Fig. 47.

is a circle 3 inches in diameter; divide the lower half into equal spaces and number the points of division 1 to 7. Now follow the rule previously given: The top and bottom piece equals 2; then for a two-pieced elbow divide 90 by 2. In its proper position below the section A draw B C D E making E D 45°. From the various points of intersection in A drop vertical lines intersecting E D as

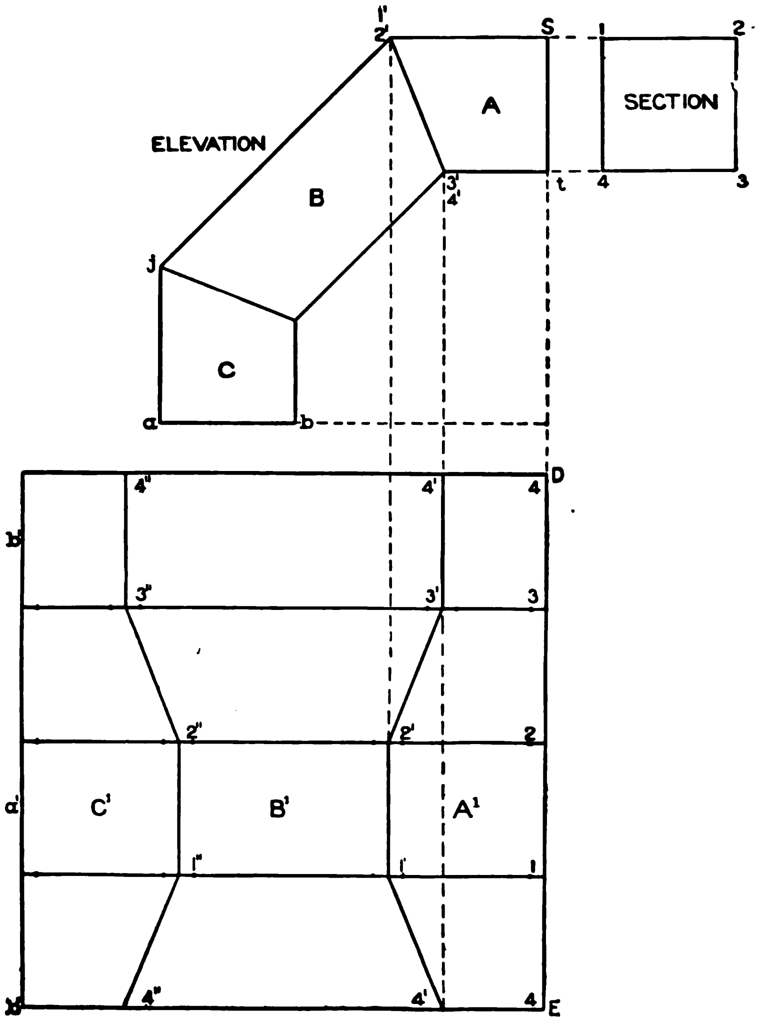



Fig. 48.

shown. In line with B C draw K L upon which place twice the number of spaces contained in the section A as shown by similar figures on K L; from these points drop perpendiculars to intersect with lines drawn from similar intersections on E D, parallel to K L. Trace a line through points shown; then K L O N·M will be the pattern. To this laps must be allowed for seaming.

Now to obtain the pattern for a three-pieced elbow, follow the rule. Top and bottom pieces equal 2, one middle piece equals 2; total 4. $\frac{90}{4} = 22\frac{1}{2}$. Therefore in line with the section A below the two-pieced elbow draw F G J H, making H J at an angle of $22\frac{1}{2}°$ to the line H *b*. Proceed as above using the same stretchout lines; then U P R S T will be the desired pattern. It should be understood that when the protractor is used for obtaining the angle as shown in Fig. 45, the heights *a c* and *b* d measured from the horizontal line form the basis for obtaining the heights of the middle pieces, inasmuch as they represent one-half the distance; for that reason the middle pieces count 2 when using the rule. Therefore, the distances F H and G J (Fig. 47), represent one-half of the center piece and U T S R P one-half the pattern for the center piece of a three-pieced elbow.

Fig. 48 shows how the patterns are laid into one another, to prevent waste of metal when cutting. In this example we have a three-pieced elbow whose section is 2 × 2 inches. It is to be laid out in a quadrant whose radius is 5 inches. Use the same principles for square section as for round; number the corners of the section 1 to 4. In line with S *t* draw D E upon which place the stretchout of the square section as shown by similar numbers on D E; from which draw horizontal lines which intersect lines drawn parallel to D E from the intersections 1′ 2′ and 3′ 4′ in A in elevation, thus obtaining similar points in the pattern. Then $A^1$ will be the pattern for A in elevation. For the pattern for B simply take the distance from 2′ to *j* and place it on the line 4 4′ extended in the pattern on either side as shown by 4′ 4″ on both sides. Now reverse the cut 4′ 2′ 4′ and obtain 4″ 2″ 4″. By measurement it will be found that 4′ 4″ is twice the length of 2′ 2 as explained in connection with Figs. 45 and 47. Make the distance from 1″ to *a′* the same as *j* to *a* in C and draw the vertical line *b′ b′* intersecting the lines 4 4″ extended on both sides. Then $A^1$, $B^1$, and $C^1$ will be the patterns in one piece minus the edges for seaming which must be allowed between these cuts; this would of course make the lengths b′ 4″, 4″ 4′ and 4′ 4 as much longer as the laps would necessitate.

This method of cutting elbows in one piece, from one square is applicable to either round, oval or square sections.

In Figs. 49 and 50 are shown three-pieced elbows such as are

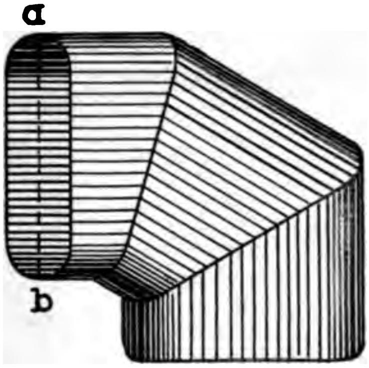



Fig. 49.

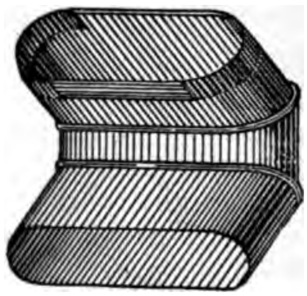


Fig. 50.

used in furnace-pipe work and are usually made from bright tin. Note the difference in the position of the sections of the two elbows. In Fig. 49 *a b* is in a vertical position, while in Fig. 50 it is in a horizontal position. In obtaining the patterns the same rule is employed as in previous problems, care being taken when developing the patterns for Fig. 49 that the section be placed as in Fig. 51 at A; and when developing the patterns for Fig. 50, that the section be placed as shown at A in Fig. 52.

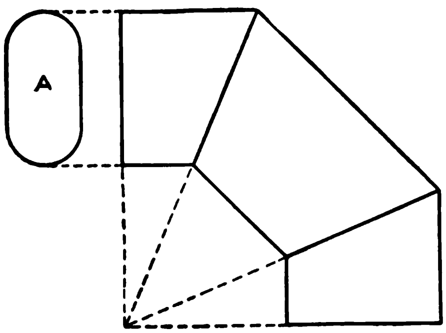



Fig. 51.

Fig. 53 shows a tapering two-pieced elbow, round in section. The method here shown is short and while not strictly accurate, gives good results. It has been shown in previous problems on Intersections and Developments that an oblique section through the opposite sides of a cone is a true ellipse. Bearing this in mind it is evident that if the frustum of the cone H I O N, Fig. 54, were a solid and cut obliquely by the plane J K and the several parts placed side by side, both would present true ellipses of exactly the same size, and if the two parts were placed together again turning the upper piece half-way around as shown by J W M K, the edges

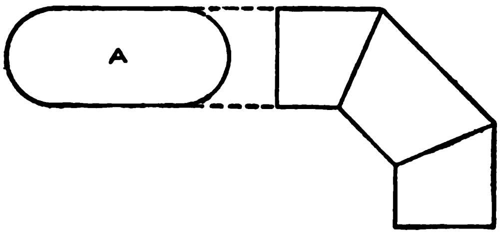



Fig. 52.

of the two pieces from J to K would exactly coincide. Taking advantage of this fact, it is necessary only to ascertain the angle of the line J K, to produce the required angle, between the two pieces of the elbow, both of which have an equal flare. The angle of the miter line, or the line which cuts the cone in two parts, must be found accurately so that when joined together an elbow will be formed having the desired angle on the line of its axis.

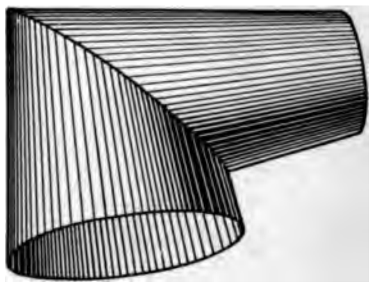


Fig. 53.

Therefore draw any vertical line as A B. With C as a center describe the plan of the desired diameter as shown by E D F B. At right angles to A B draw the bottom line of the elbow H I equal to E F, or in this case, 3 inches. Measuring from the line H I on the line A B the height of the frustum is 5 inches. Through X′ draw the upper diameter O N, 1½ inches. Extend the contour lines of the frustum until they intersect the center line at L. Divide the half plan E D F into a number of equal parts as shown; from these points erect lines intersecting the base line H I from which draw lines to the apex L. As the elbow is to be in two pieces, and the axis at right angles, draw the angle T R S, bisect it at U and draw the line R V. No matter what the angle of the elbow, use this method. Now establish the point J at some convenient point on the cone, and from J, parallel to R V, draw the miter line J K intersecting the radial lines drawn through the cone; from these points and at right angles to the center line A B draw lines intersecting the side of the cone J H from 1 to 7. If it is

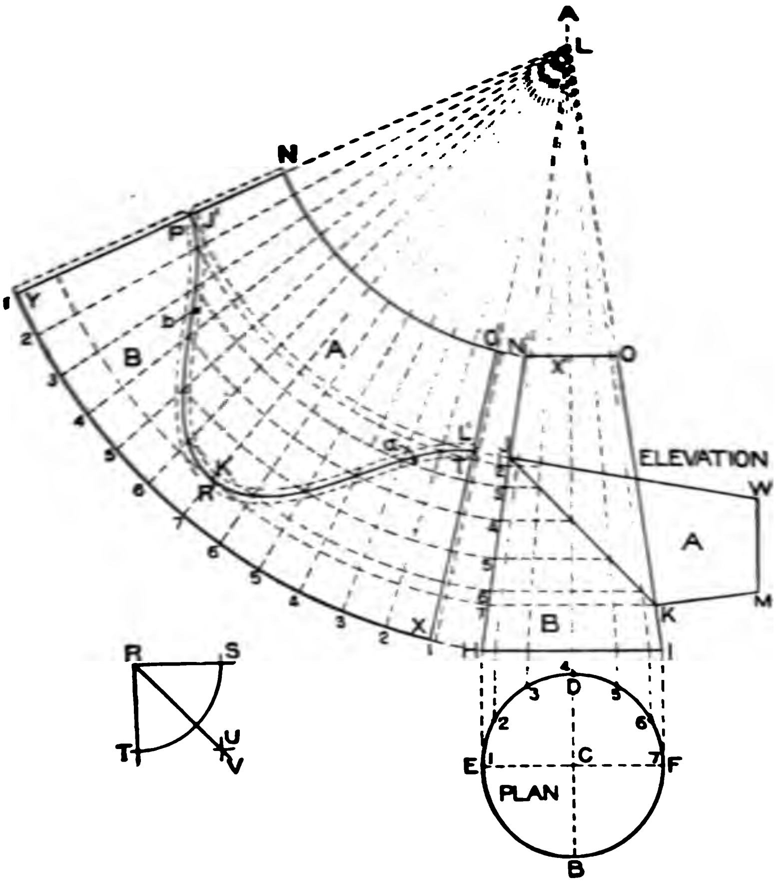



Fig. 54.

desired to know how the side of the tapering elbow would look, take a tracing of N O K J, reverse it and place it as shown by J W M K.

For the pattern proceed as follows: With L as a center and L H as a radius describe the arc 1 1. Starting from 1 set off on this arc twice the stretchout of 1 4 7 in plan, as shown by similar figures on 1 1, from which draw radial lines to the apex L. Again using L as center with radii equal to L N, L 1, L 2 to L 7, draw arcs as shown intersecting radial lines having similar numbers. Through these intersections draw the line J′ L′. Then O′ N′ J′ K′ L′ or A will be the pattern for the upper arm (A) in elevation, and P′ R′ T′ X Y or B the pattern for the lower arm (B) in elevation.

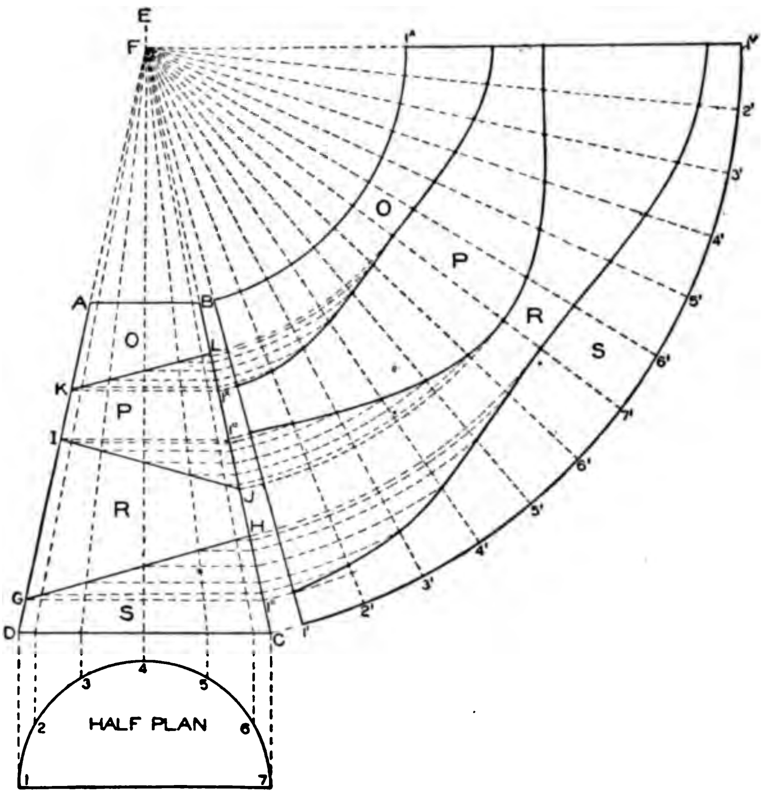



Fig. 55.

The pattern should be developed full size in practice and then pricked from the paper on to the sheet metal, drawing the two patterns as far apart as to admit allowing an edge to A at *a*; also an edge at *b* to B for seaming.

When a pattern is to contain more than two pieces the method of constructing the miter lines in the elevation of the cone is slightly different as shown in Fig. 55. Assume the bottom to be 3 inches in diameter and the top $1\frac{1}{4}$ inches. Let the vertical height be 4 inches. In this problem, as in the preceding, the various pieces necessary to form the elbow are cut from one cone whose dimensions must be determined from the dimensions of the required elbow. The first step is to determine the miter lines, which can be done the same as if regular pieced elbows were being developed. As the elbow is to consist of four pieces in 90°, follow the rule given in connection with elbow drafting. The top and bottom piece equal 2; the two middle pieces equal 4; total 6. $\frac{90}{6} = 15$. Lay off A B C D according to the dimensions given, and draw the half plan below D C; divide it into equal parts as shown. From the points of division erect perpendiculars intersecting D C, from which draw lines meeting the center line E 4 at F.

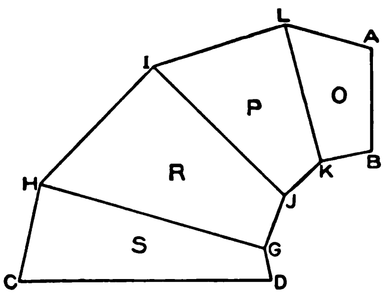



Fig. 56.

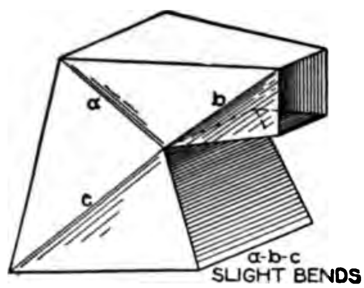



Fig. 57.

We assume that the amount of rise and projection of the elbow are not specified, excepting that the lines of axis will be at right angles. Knowing the angle of the miter line, it becomes a matter of judgment upon the part of the pattern draftsman, what length shall be given to each of the pieces composing the elbow. Therefore establish the points G, I and K, making D G, G I, I K and K A, $\frac{1}{2}$, $1\frac{7}{8}$, $\frac{3}{4}$ and 1 inch respectively. From G, I and K draw the horizontal lines G 1′, I 1° and K $1^x$. To each of these lines draw the lines G H, I J and K L respectively at an angle of 15° intersecting the radial lines in the cone as shown. From these intersections draw horizontal lines cutting the side of the cone. Then using F as a center, obtain the various patterns O, P, R and S in the manner already explained.

In Fig. 56 is shown a side view of the elbow, resulting from preceding operations; while it can be drawn from dimensions obtained in Fig. 55, it would be impossible to draw it without first having these dimensions.

In Fig. 57 is shown a perspective view of a tapering square elbow of square section in two pieces. This elbow may have any given taper. This problem will be developed by triangulation and parallel lines; it is an interesting study in projections as well as in developments. First draw the elevation of the elbow in Fig. 58 making 1–6 equal to $3\frac{1}{2}$ inches, the vertical height 1–2, $4\frac{1}{2}$ inches, and 6–5, $2\frac{1}{2}$ inches; the projection between 1 and 2 should be $\frac{5}{8}$ inch and between 5 and 6, $\frac{3}{8}$ inch. Make the horizontal distance

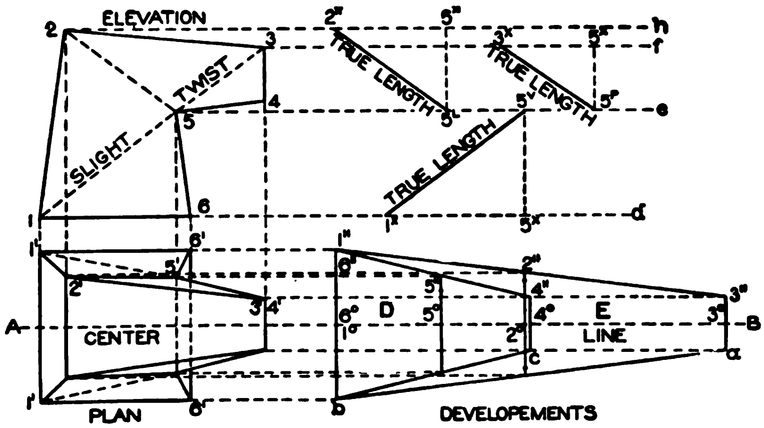



Fig. 58.

from 5 to 4, 2 inches, and the riso at 4 from the horizontal line $\frac{1}{4}$ inch, and the vertical distance from 4 to 3, $1\frac{1}{4}$ inches. Then draw a line from 3 to 2 to complete the elevation.

In its proper position below the line 1–6, draw the plan on that line, as shown by 1′ 1′ 6′ 6′. Through this line draw the center line A B. As the elbow should have a true taper from 1 to 3 and from 4 to 6, we may develop the patterns for the top and bottom pieces first and then from these construct the plan. Therefore, take the distances from 1 to 2 to 3 and from 4 to 5 to 6 in elevation and place them on the line A B in plan as shown respectively from 1° to 2° to 3° and from 4° to 5° to 6°; through these points draw vertical lines as shown. While the full developments

**E and D are shown we shall deal with but one-half in the explanation which follows. As the elbow is to have the same taper on either side, take the half distance of the bottom of the elbow 1–6 and place it as shown from $1^{\circ}$–$6^{\circ}$ to $1'$–$6'$, and the half width of the top of the elbow 3–4 and place it as shown from $3^{\circ}$ to $3'$ and $4^{\circ}$ to $4'$. Then draw lines from $3'$ to $1'$ intersecting the bend $2^{\circ}$ at $2'$, and a line from $4'$ to $6'$ intersecting the bend $5^{\circ}$ at $5'$. Trace these points on the opposite side of the line A B. Then $1'$ $3'$ *a b* will be the pattern for the top of the elbow and $6'$ $4'$ *c b* the pattern for the bottom. From these various points of intersection draw horizontal lines to the plan, and intersect them by lines drawn from similarly numbered points in the elevation at right angles to A B in plan. Draw lines through the points thus** obtained in plan as shown by $1'$, $2'$, $3'$, $4'$, $5'$ and $6'$ which will represent the half plan view. For the completed plan, trace these lines opposite the line A B as shown. It will be noticed that the line 3–4 in elevation is perpendicular as shown by $3'$ $4'$ in plan while the points $2'$ and $5'$ project from it, showing that the piece 2–3–4–5 in elevation must be slightly twisted along the line 5–3 when forming the elbow. Similarly slight bends will be required along the lines 1–5 and 5–2.

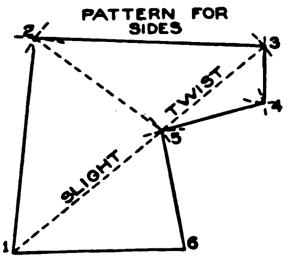


Fig. 59.

It will now be necessary to obtain the true lengths or a diagram of triangles on the lines 1–5, 5–2 and 5–3. Connect similar numbers in plan as shown from $1'$ to $5'$, $5'$ to $2'$ and $5'$ to $3'$, the last two lines being already shown. From similar points in elevation draw horizontal lines as shown by 2–*h*, 3–*f*, 5–*e* and 6–*d*. Take the distances from $1'$ to $5'$, $5'$ to $2'$ and $5'$ to $3'$ in plan and place them on one of the lines having a similar number in elevation, as shown respectively by $1^x$ $5^x$, $5^x$ $2^x$ and $5^x$ $3^x$. From the points marked $5^x$ draw vertical lines intersecting the horizontal line drawn from 5 at $5^v$, $5^L$ and $5^p$ respectively. Now draw the true lengths $1^x$ $5^v$, $2^x$ $5^L$, and $3^x$ $5^p$. For the pattern draw any line as 1–6 in Fig. 59 equal to 1–6 in Fig. 58. Now with $6'$ $5'$ in D as a radius and 6 in Fig. 59 as a center, describe the arc 5 which is intersected by an arc struck from 1 as a center and the true length

$1^x\ 5^v$ in Fig. 58 as radius. Then using the true length $5^L\ 2^x$ as radius and 5 in Fig. 59 as center, describe the arc 2, which is intersected by an arc struck from 1 as center and 1′ 2′ in E in Fig. 58 as radius. Using the true length $5^p\ 3^x$ as radius and 5 in Fig. 59 as center, describe the arc 3, and intersect it by an arc struck from 2 as center and 2′ 3′ in E in Fig. 58 as a radius. Now with 5′ 4′ in D as a radius and 5 in Fig. 59 as a center, describe the arc 4, and intersect it by an arc struck from 3 as center and 3–4 in the elevation in Fig. 58 as a radius. Draw lines from point to point in Fig. 59 to complete the pattern. Laps should be allowed on all patterns, for seaming. Slight bends will take place as shown on the pattern, also as is shown by *a b* and *c* in Fig. 57. If the joint is to be on the line 2–5 in elevation in Fig. 58, the necessary pieces can be joined together.

In Fig. 60 is shown a perspective view of a five-piece tapering elbow, having a round base and an elliptical top. This form is generally known as a *ship ventilator*. The principles shown in this problem are applicable to any form or shape no matter what the respective profiles may be at the base or top. The first step is to draw a correct side view of the elbow as shown in Fig. 61. The outline A B C D E F can be drawn at pleasure, but for practice, dimensions are given. First draw the vertical line A F equal to 4½ inches. On the same line extend measure down 1¼ inches to *f* and draw the horizontal line H B. From *f* set off a distance of 1¼ inches at G, and using G as a center and G F as a radius describe the arc F E intersecting H B at E, from which draw the vertical line E D equal to 1 inch. Draw D C equal to 1¾ inches, then draw C B. From B lay off 5¾ inches, and using this point (H) as a center and H B as a radius describe the arc B A. The portion shown B E D C is a straight piece of pipe whose section is shown by I J K L. Now divide the two arcs B A and E F into the same number of parts that the elbow is to have pieces (in this case four) and draw the lines of joint or miter lines as shown by U V, etc.

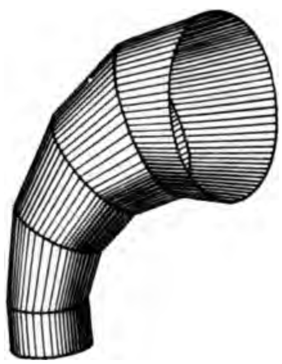


Fig. 60.

Bisect each one of the joint lines and obtain the points *a b c d* and *e*. Then A B C D E F will be the side view.

The patterns will be developed by triangulation, but before this can be done, true sections must be obtained on all of the lines in side elevation. The true sections on the lines B E and C D are shown by I J K L. The length of the sections are shown by the joint lines, but the width must be obtained from a front outline of the elbow, which is constructed as follows: In its proper relation to the side elevation, draw the center line M R upon which draw

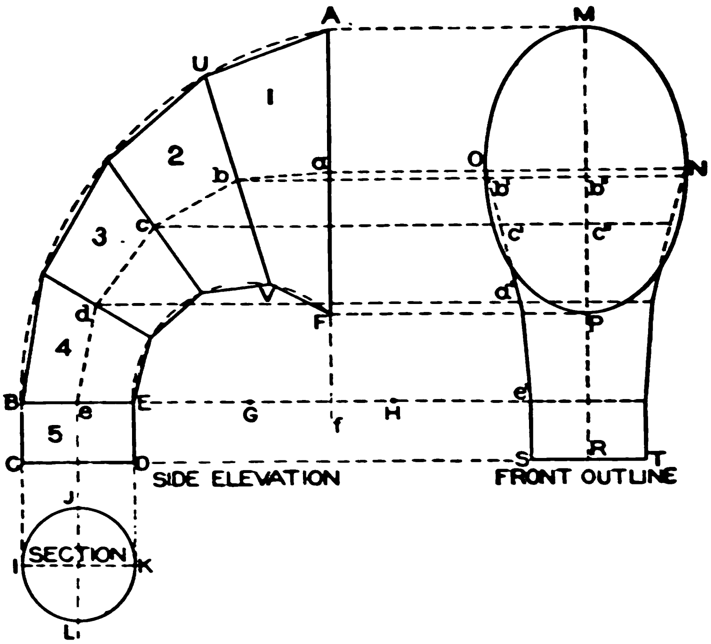



Fig. 61.

the ellipse M N O P (by methods already given in Mechanical Drawing) which represents the section on A F in side. Take half the diameter I K in section and place it on either side of the center line M R as R T or R S. Then draw the outline O S and T N in a convenient location. While this line is drawn at will, it should be understood that when once drawn, it becomes a fixed line. Now from the various intersections *a b c d* and *e* in the side elevation, draw lines through and intersecting the front outline as shown on one side by O, $b'$, $c'$, $d'$ and $e'$. Then these distances will represent the widths of the sections shown by similar letters in side. For example, the method will be shown for obtaining the true section on U V, and the pattern for piece 1 in side elevation. To avoid a confusion of lines take a tracing of A F V U and place it as shown by 1, 13, 12, O in Fig. 62. On 1–13 place the half profile M N P of Fig. 61. Bisect O–12 in Fig. 62 and obtain the point 6; at a right angle to O–12 from 6 draw the line 6 6′ equal to $b'$ $b''$ in front outline in Fig. 61. Then through the three points O, 6′ and 12 in Fig. 62, draw the semi-ellipse, which will represent the half section on U V. The other

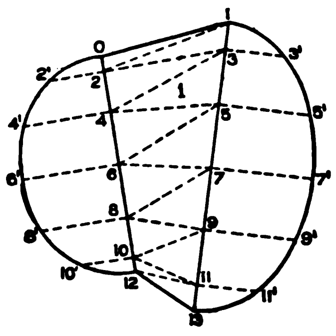


Fig. 62.

sections on the joint lines in side elevation are obtained in the same manner.

If the sections were required for piece 2 in side it would be necessary to use only O 6′ 12 in Fig. 62 and place it on U V in Fig. 61, and on a perpendicular line erected from $c$, place the width $c'$ $c''$ shown in front and through the three points obtained again draw the semi-elliptical profile or section. Now divide the two half sections (Fig. 62) into equal parts as shown by the small figures, from which at right angles to 1–13 and O–12 draw lines intersecting these base lines from 1–13. Connect opposite points as 1 to 2 to 3 to 4 to 5, etc., to 12. Then these lines will represent

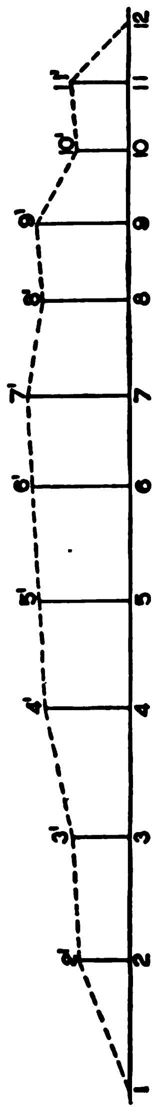


Fig. 63.

the bases of sections whose altitudes are equal to the heights in the half section. For these heights proceed as follows:

Take the various lengths from 1 to 2, 2 to 3, 3 to 4, 4 to 5, etc., to 11 to 12 and place them on the horizontal line in Fig. 63 as shown by similar figures; from these points erect vertical lines equal in height to similar figures, in the half section in Fig. 62 as shown by similar figures in Fig. 63. For example: Take the distance from 7 to 8 in Fig. 62 and place it as shown from 7 to 8 in Fig. 63 and erect vertical lines 7–7′, and 8–8′ equal to 7–7′ and 8–8′ in Fig. 62. Draw a line from 7′ to 8′ in Fig. 63 which is the true length on 7–8 in Fig. 62. For the pattern take the distance of 1–O and place it as shown by 1–O in Fig. 64. Now using O as a center and O 2′ in Fig. 62 as a radius, describe the arc 2 in Fig. 64

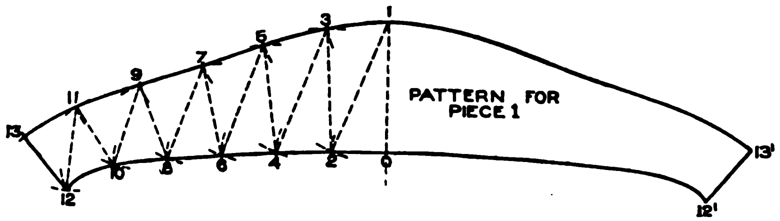



Fig. 64.

and intersect it by an arc struck from 1 as a center with 1–2′ in Fig. 63 as a radius. Now with 1–3′ in Fig. 62 as a radius and 1 in Fig. 64 as a center, describe the arc 3, and intersect it by an arc struck from 2 as center and 2′–3′ in Fig. 63 as a radius. Proceed thus, using alternately as radii, first the divisions in O–6′–12 in Fig. 62, then the proper line in Fig. 63, the divisions in 1–7′–13 in Fig. 62 and again the proper line in Fig. 63, until the line 12–13 in Fig. 64 is obtained, which equals 12–13 in Fig. 62. In this manner all of the sections are obtained, to which laps must be allowed for wiring and seaming.

## SHEET COPPER.

Official table adopted by the Association of Copper Manufacturers of the United States. Rolled copper has specific gravity of 8.93. One cubic foot weighs 558.125 pounds. One square foot, one inch thick, weighs 46.51 pounds.

| Stubs' Gauge, (nearest number). | Thickness in decimal parts of an inch. | Ounces per sq. ft. | Sheets 14″ x 48″ Weight in pounds. | Sheets 24″ x 48″ Weight in pounds. | Sheets 30″ x 60″ Weight in pounds. | Sheets 36″ x 72″ Weight in pounds. | Sheets 48″ x 72″ Weight in pounds. |
|---|---|---|---|---|---|---|---|
| 35 | .00537 | 4 | 1.16 | 2 | 3.12 | 4.50 | 6 |
| 33 | .00806 | 6 | 1.75 | 3 | 4.68 | 6.75 | 9 |
| 31 | .0107 | 8 | 2.33 | 4 | 6.25 | 9 | 12 |
| 29 | .0134 | 10 | 2.91 | 5 | 7.81 | 11.25 | 15 |
| 27 | .0161 | 12 | 3.50 | 6 | 9.37 | 13.50 | 18 |
| 26 | .0188 | 14 | 4.08 | 7 | 10.93 | 15.75 | 21 |
| 24 | .0215 | 16 | 4.66 | 8 | 12.50 | 18 | 24 |
| 23 | .0242 | 18 | 5.25 | 9 | 14.06 | 20.25 | 27 |
| 22 | .0269 | 20 | 5.83 | 10 | 15.62 | 22.50 | 30 |
| 21 | .0322 | 24 | 7 | 12 | 18.75 | 27 | 36 |
| 19 | .0430 | 32 | 9.33 | 16 | 25 | 36 | 48 |
| 18 | .0538 | 40 | 11.66 | 20 | 31.25 | 45 | 60 |
| 16 | .0645 | 48 | 14 | 24 | 37.50 | 54 | 72 |
| 15 | .0754 | 56 | 16.33 | 28 | 43.75 | 63 | 84 |
| 14 | .0860 | 64 | 18.66 | 32 | 50 | 72 | 96 |
| 13 | .095 | 70 | .... | 35 | 55 | 79 | 105 |
| 12 | .109 | 81 | .... | 40½ | 63 | 91 | 122 |
| 11 | .120 | 89 | .... | 44½ | 70 | 100 | 134 |
| 10 | .134 | 100 | .... | 50 | 78 | 112 | 150 |
| 9 | .148 | 110 | .... | 55 | 86 | 124 | 165 |
| 8 | .165 | 123 | .... | 61 | 96 | 138 | 184 |
| 7 | .180 | 134 | .... | 67 | 105 | 151 | 201 |
| 6 | .203 | 151 | .... | 75½ | 118 | 170 | 227 |
| 5 | .220 | 164 | .... | 82 | 128 | 184 | 246 |
| 4 | .238 | 177 | .... | 88½ | 138 | 199 | 266 |
| 3 | .259 | 193 | .... | 96 | 151 | 217 | 289 |
| 2 | .284 | 211 | .... | 105½ | 165 | 238 | 317 |
| 1 | .300 | 223 | .... | 111½ | 174 | 251 | 335 |
| 0 | .340 | 253 | .... | 126½ | 198 | 285 | 380 |

## SHEET ZINC.

| Numbers | | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight per sq. foot | | .30 | .37 | .45 | .52 | .60 | .67 | .75 | .90 | 1.05 | 1.20 | 1.35 | 1.50 | 1.68 | 1.87 | 2.06 | 2.25 | 2.62 | 3.00 | 3.37 |
| Approximate thickness in inches | | .008 | .010 | .012 | .014 | .016 | .018 | .020 | .024 | .028 | .032 | .036 | .040 | .045 | .050 | .055 | .060 | .070 | .080 | .090 |
| Size of sheet. | Sq. ft. per sheet. | APPROXIMATE WEIGHT PER SHEET. | | | | | | | | | | | | | | | | | | |
| · in. | 14. | 4.2 | 5.2 | 6.3 | 7.3 | 8.4 | 9.4 | 10.5 | 12.6 | 14.7 | 16.8 | 18.9 | 21. | 23.5 | 26.2 | 28.9 | 31.5 | 36.7 | 42. | 47.2 |
| | 15.2 | 4.6 | 5.6 | 6.9 | 7.9 | 9.1 | 10.2 | 11.4 | 13.7 | 16. | 18.3 | 20.5 | 22.8 | 25.6 | 28.4 | 31.3 | 34.2 | 39.9 | 45.6 | 51.2 |
| | 16.3 | 4.9 | 6. | 7.4 | 8.5 | 9.8 | 10.9 | 12.2 | 14.7 | 17.1 | 19.6 | 22. | 24.5 | 27.4 | 30.5 | 33.6 | 36.7 | 42.7 | 48.9 | 54.9 |
| | 17.5 | 5.3 | 6.5 | 7.9 | 9.1 | 10.5 | 11.8 | 13.2 | 15.8 | 18.4 | 21. | 23.6 | 26.2 | 29.4 | 32.8 | 36.1 | 39.4 | 45.8 | 52.5 | 59. |
| | 18.7 | 5.6 | 6.9 | 8.4 | 9.7 | 11.2 | 12.6 | 14.1 | 16.9 | 19.7 | 22.5 | 25.3 | 32.8 | 31.4 | 35. | 38.5 | 42. | 49. | 56.1 | 63. |
| | 19.9 | 6.0 | 7.4 | 9. | 10.4 | 12. | 13.4 | 15. | 18. | 20.9 | 23.9 | 26.9 | 29.9 | 33.4 | 37.2 | 41. | 44.8 | 52.2 | 59.7 | 67. |
| | 21. | 6.3 | 7.8 | 9.5 | 10.9 | 12.6 | 14.1 | 15.8 | 18.9 | 22. | 25.2 | 28.4 | 31.5 | 35.3 | 39.3 | 43.3 | 47.2 | 55. | 63. | 70.8 |
| | 24. | 7.2 | 8.9 | 10.8 | 12.5 | 14.4 | 16.1 | 18. | 21.6 | 25.2 | 28.8 | 32.4 | 36. | 40.3 | 44.9 | 49.5 | 54. | 62.8 | 72. | 80.9 |
| 108. | 27. | 8.1 | 10. | 12.2 | 14.1 | 16.2 | 18.1 | 20.3 | 24.3 | 28.4 | 32.4 | 36.5 | 40.5 | 45.4 | 50.5 | 55.6 | 60.7 | 70.7 | 81. | 91. |
| 84. | 23.4 | 7. | 8.7 | 10.6 | 12.2 | 14.1 | 15.7 | 17.6 | 21. | 24.6 | 28.1 | 31.6 | 35.1 | 39.3 | 43.8 | 48.2 | 52.6 | 61.3 | 70.2 | 78.8 |
| 96. | 26.8 | 8. | 9.9 | 12.1 | 14. | 16.1 | 18. | 20.1 | 24.1 | 28.1 | 32.2 | 36.2 | 40.2 | 45. | 50.1 | 55.2 | 60.3 | 70.2 | 80.4 | 90.3 |
| 84. | 25.7 | 7.7 | 9.5 | 11.6 | 13.4 | 15.4 | 17.2 | 19.3 | 23.1 | 27. | 30.8 | 34.7 | 38.6 | 43.2 | 48.1 | 53. | 57.8 | 67.4 | 77.1 | 86.6 |
| x 90. | 28.7 | 8.6 | 10.6 | 12.9 | 14.9 | 17.2 | 19.2 | 21.5 | 25.8 | 30.1 | 34.4 | 38.7 | 43. | 48.2 | 53.7 | 59.1 | 64.6 | 75.2 | 86.1 | 96.7 |
| x 84. | 28. | 8.4 | 10.4 | 12.6 | 14.6 | 16.8 | 18.8 | 21. | 25.2 | 29.4 | 33.6 | 37.8 | 42. | 47. | 52.4 | 57.7 | 63. | 73.4 | 84. | 94.4 |
| 48 x 96. | 32. | 9.6 | 11.9 | 14.4 | 16.7 | 19.2 | 21.5 | 24. | 28.8 | 33.6 | 38.4 | 43.2 | 48. | 53.8 | 59.9 | 65.9 | 72. | 83.9 | 96. | 107.8 |
| 50 x 108. | 37.5 | 11.3 | 13.9 | 16.9 | 19.5 | 22.5 | 25.1 | 28.2 | 33.8 | 39.3 | 45. | 50.7 | 56.3 | 63. | 70.1 | 77.3 | 84.4 | 98.3 | 112.5 | 126.4 |
| 52 x 84. | 30.4 | 9.1 | 11.3 | 13.7 | 15.8 | 18.3 | 20.4 | 22.8 | 27.4 | 31.9 | 36.5 | 41. | 45.6 | 51. | 56.9 | 62.6 | 68.4 | 79.6 | 91.2 | 102.5 |

Casks average about 600 pounds each. No. 4 to No. 17. Boxes average about 500 pounds. No. 18 and heavier.

## UNITED STATES STANDARD GAUGE FOR SHEET AND PLATE IRON AND STEEL

COPY [Public—No. 137]

**An act establishing a standard gauge for sheet and plate iron and steel.**

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That for the purpose of securing uniformity the following is established as the only standard gauge for sheet and plate iron and steel in the United States of America, namely:

| Number of Gauge | THICKNESS | | WEIGHT | | Number of Gauge |
|---|---|---|---|---|---|
| | Approximate thickness in fractions of an inch | Approximate thickness in decimal parts of an inch | Weight per square foot in OUNCES avoirdupois | Weight per square foot in POUNDS avoirdupois | |
| 0000000 | 1-2 | .5 | 320 | 20. | 0000000 |
| 000000 | 15-32 | .46875 | 300 | 18.75 | 000000 |
| 00000 | 7-16 | .4375 | 280 | 17.5 | 00000 |
| 0000 | 13-32 | .40625 | 260 | 16.25 | 0000 |
| 000 | 3-8 | .375 | 240 | 15. | 000 |
| 00 | 11-32 | .34375 | 220 | 13.75 | 00 |
| 0 | 5-16 | .3125 | 200 | 12.5 | 0 |
| 1 | 9-32 | .28125 | 180 | 11.25 | 1 |
| 2 | 17-64 | .265625 | 170 | 10.625 | 2 |
| 3 | 1-4 | .25 | 160 | 10. | 3 |
| 4 | 15-64 | .234375 | 150 | 9.375 | 4 |
| 5 | 7-32 | .21875 | 140 | 8.75 | 5 |
| 6 | 13-64 | .203125 | 130 | 8.125 | 6 |
| 7 | 3-16 | .1875 | 120 | 7.5 | 7 |
| 8 | 11-64 | .171875 | 110 | 6.875 | 8 |
| 9 | 5-32 | .15625 | 100 | 6.25 | 9 |
| 10 | 9-64 | .140625 | 90 | 5.625 | 10 |
| 11 | 1-8 | .125 | 80 | 5. | 11 |
| 12 | 7-64 | .109375 | 70 | 4.375 | 12 |
| 13 | 3-32 | .09375 | 60 | 3.75 | 13 |
| 14 | 5-64 | .078125 | 50 | 3.125 | 14 |
| 15 | 9-128 | .0703125 | 45 | 2.8125 | 15 |
| 16 | 1-16 | .0625 | 40 | 2.5 | 16 |
| 17 | 9-160 | .05625 | 36 | 2.25 | 17 |
| 18 | 1-20 | .05 | 32 | 2. | 18 |
| 19 | 7-160 | .04375 | 28 | 1.75 | 19 |
| 20 | 3-80 | .0375 | 24 | 1.5 | 20 |
| 21 | 11-320 | .034375 | 22 | 1.375 | 21 |
| 22 | 1-32 | .03125 | 20 | 1.25 | 22 |
| 23 | 9-320 | .028125 | 18 | 1.125 | 23 |
| 24 | 1-40 | .025 | 16 | 1. | 24 |
| 25 | 7-320 | .021875 | 14 | .875 | 25 |
| 26 | 3-160 | .01875 | 12 | .75 | 26 |
| 27 | 11-640 | .0171875 | 11 | .6875 | 27 |
| 28 | 1-64 | .015625 | 10 | .625 | 28 |
| 29 | 9-640 | .0140625 | 9 | .5625 | 29 |
| 30 | 1-80 | .0125 | 8 | .5 | 30 |
| 31 | 7-640 | .0109375 | 7 | .4375 | 31 |
| 32 | 13-1280 | .01015625 | 6½ | .40625 | 32 |
| 33 | 3-320 | .009375 | 6 | .375 | 33 |
| 34 | 11-1280 | .00859375 | 5½ | .34375 | 34 |
| 35 | 5-640 | .0078125 | 5 | .3125 | 35 |
| 36 | 9-1280 | .00703125 | 4½ | .28125 | 36 |
| 37 | 17-2560 | .0066406 | 4¼ | .265625 | 37 |
| 38 | 1-160 | .00625 | 4 | .25 | 38 |

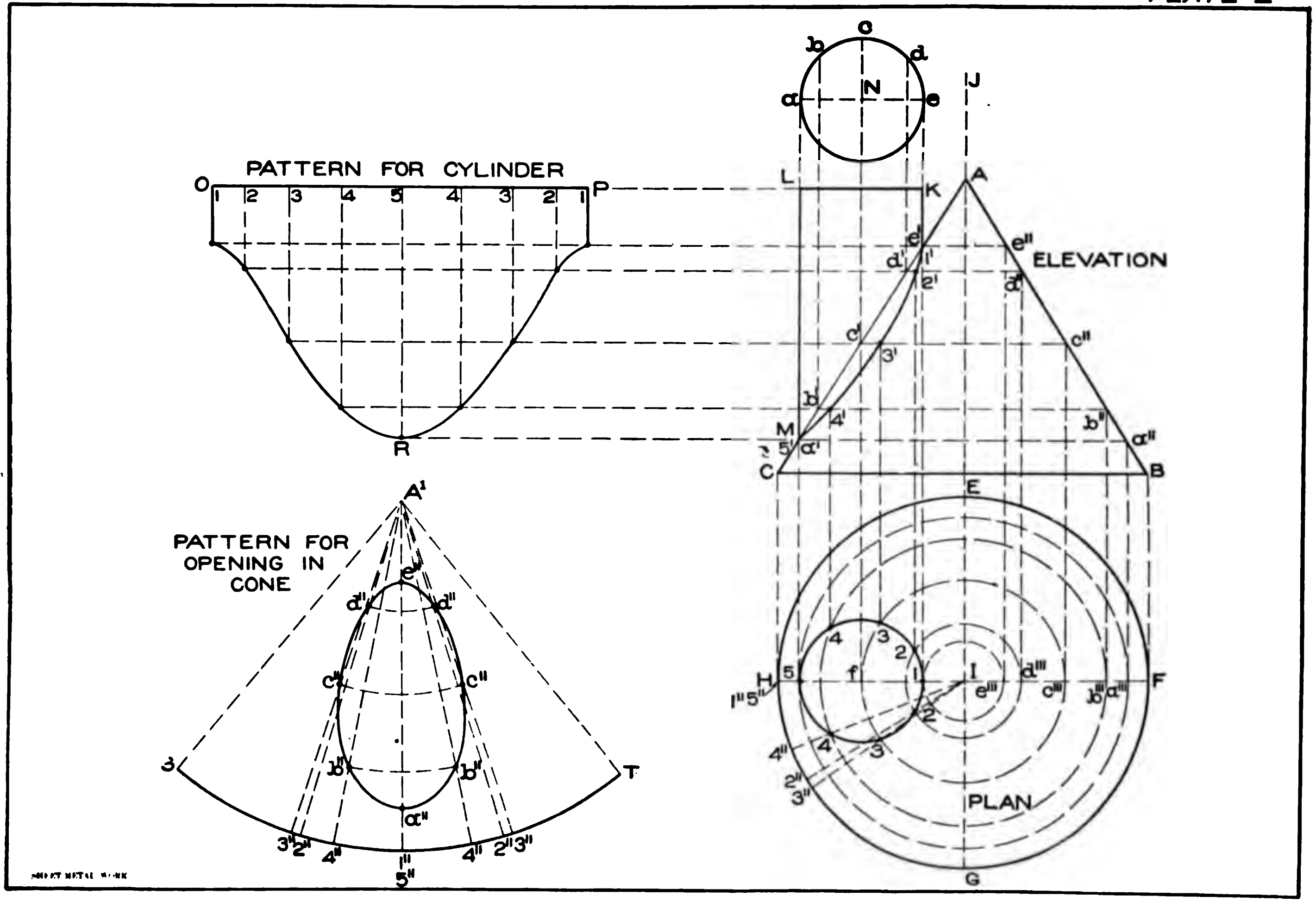
And on and after July first, eighteen hundred and ninety-three, the same and no other shall be used in determining duties and taxes levied by the United States of America on sheet and plate iron and steel. But this act shall not be construed to increase duties upon any articles which may be imported.

SEC. 2. That the Secretary of the Treasury is authorized and required to prepare suitable standards in accordance herewith.

SEC. 3. That in the practical use and application of the standard gauge hereby established a variation of two and one-half per cent either way may be allowed.

Approved, March 3, 1893.

PLATE I


PATTERN FOR CYLINDER
O
P
R
ELEVATION
PLAN
PATTERN FOR OPENING IN CONE
A
B
C
E
F
G
H
I
J
K
L
M
N
T

## EXAMINATION PLATES.

### PLATE I.

The plates of this Instruction Paper should be laid out the same size as explained in the course on Tinsmith's Work. Before starting these plates the student should first practice on other paper and make models of stiff cardboard to prove the accuracy of the patterns. When the problem is thoroughly mastered and understood, copy and send in your best drawing for examination and correction.

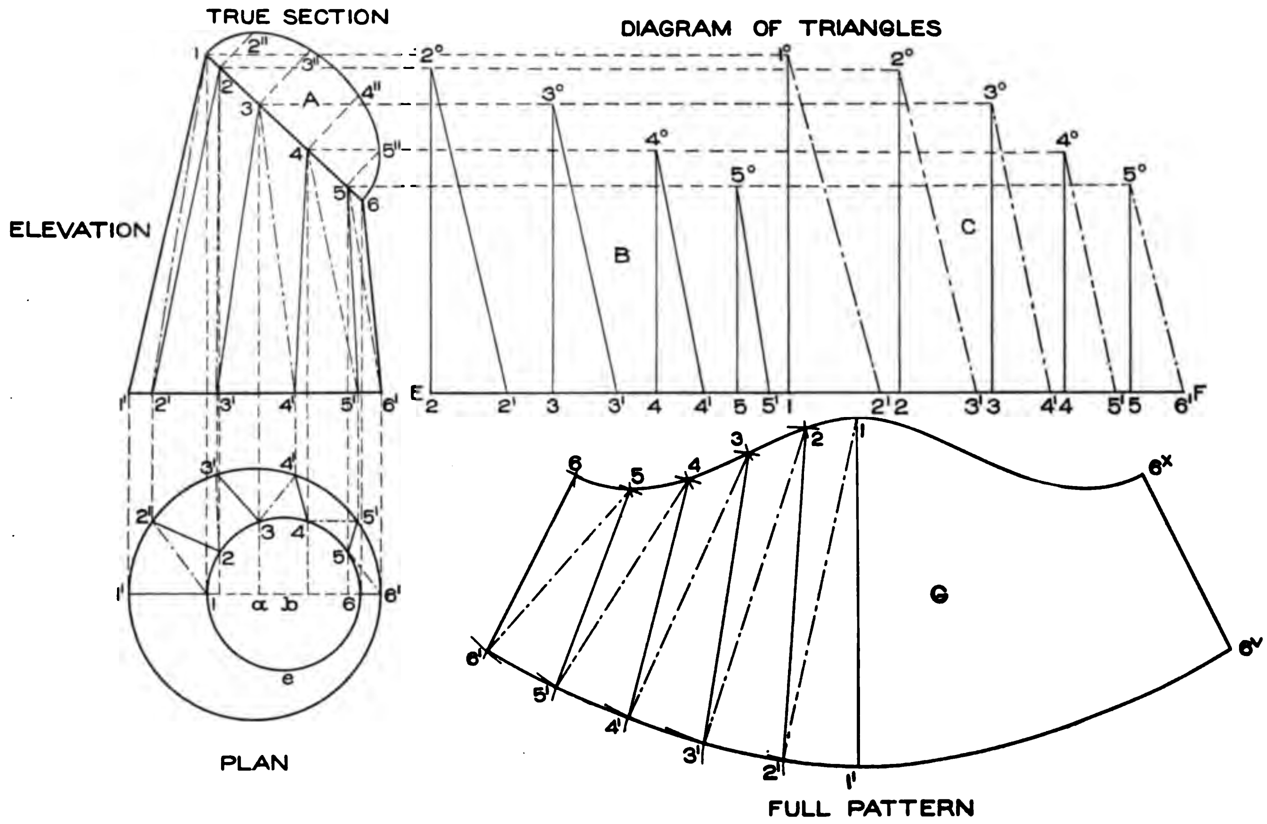
The first problem given is the intersection and development of a cylinder and a right cone, whose lines of axis run parallel to each other. First draw the base of the cone B C 4¼ inches long, placing B 1½ inches from the border line, and the line C B 5¼ inches above the bottom line. Make the vertical height of the cone 3½ inches, and draw the lines A B and A C. Through A draw the center vertical line J G, on which 2½ inches below the base line C B establish the point I. Now with I as center and ½ of C B as radius, describe the circle E F G H, which represents the plan of the cone. From A on the line A C measure down one inch as shown at $e'$, from which erect a vertical line $e'$ K ¾-inch high. From K draw the horizontal line K L equal to 1⅝ inches, and from L drop a perpendicular intersecting the side of the cone at M. Directly above L K in its proper relative position ¼-inch above L K, with N as center draw the circle shown, which represents a section through L K. Through the center N draw the horizontal line *a e*. Now divide the half upper section N into an equal number of spaces as shown by *a b c d e*, from which points drop vertical lines intersecting the side of the cone A C at $a'$ $b'$ $c'$ $d'$ and $e'$, and from these points, draw horizontal lines, intersecting the opposite side A B from $a''$ to $e''$.

The next step is to construct planes in plan as follows: From the various intersections $a''$ to $e''$ in elevation, drop vertical lines intersecting the horizontal line H F in plan drawn through the center I, at $a'''$ $b'''$ $c'''$ $d'''$ and $e'''$. Then using I as center and distances to points $a'''$ to $e'''$ as radii, strike the various circles shown. From the center of the section N in elevation extend the line intersecting H F in plan at *f*; then using *f* as center and N *a* or N $e$ in elevation as radius, describe the circle 1–3–5–3 in plan, cutting the various planes at 1, 2, 3, 4, and 5 on both sides. Now, from the various points of intersection on the various planes in plan, erect lines intersecting similarly lettered planes in elevation as shown at 1′, 2′, 3′, 4′, and 5′, through which trace a line as shown, which represents the line of intersection between the cylinder and right cone.

For the pattern for the cylinder proceed as follows: Extend the line K L of the cylinder in elevation as shown by O P, placing the distance 1 from the margin line 2½ inches. Now starting from 1, lay off on O P the stretchout of the section $f$ in plan, the spaces being designated by similar figures on O P. From these small figures and at right angles to O P, draw lines which intersect with lines drawn from similarly numbered intersections on the line of intersection in elevation parallel to O P. Trace a line through points thus obtained. Then will O P R be the full pattern for the cylinder.

The pattern for the right cone is developed as has already been described in the Tinsmith's Course, and for that reason will be shown only the method how to obtain the pattern for the opening in the cone to miter with the cylinder. For this proceed as follows: Draw radial lines from I in plan through the intersections 1, 2, 3, 4, and 5, cutting the outer curve E F G H at 1″, 2″, 3″, 4″, and 5″, respectively. Now with A B in elevation as radius and $A^1$ as center, describe a short arc as S T. Place the arc as far above the margin line as the plan G, and have S T central between the plan and margin line. From $A^1$ drop a vertical line intersecting the arc S T at 1″. Now starting from 1″, set off on either side of the center line $A^1$ 1″ the distances shown in plan from 1″ 5″ to 4″ to 2″ to 3″, as shown by similar numbers on S T. From these points draw radial lines to $A^1$. Now using $A^1$ as center and with radii equal to A $e'$, A $d'$, A $c'$, A $b'$, and A $a'$ in elevation, describe arcs intersecting respectively the radial lines A′ 1″ at $e''$, 2″ 2″ at $d''$ $d''$, 3″ 3″ at $c''$ $c''$, 4″ 4″ at $b''$ $b''$, and A′ 5″ at $a''$. Through these intersections trace a line as shown, which will be the desired opening.

PLATE II



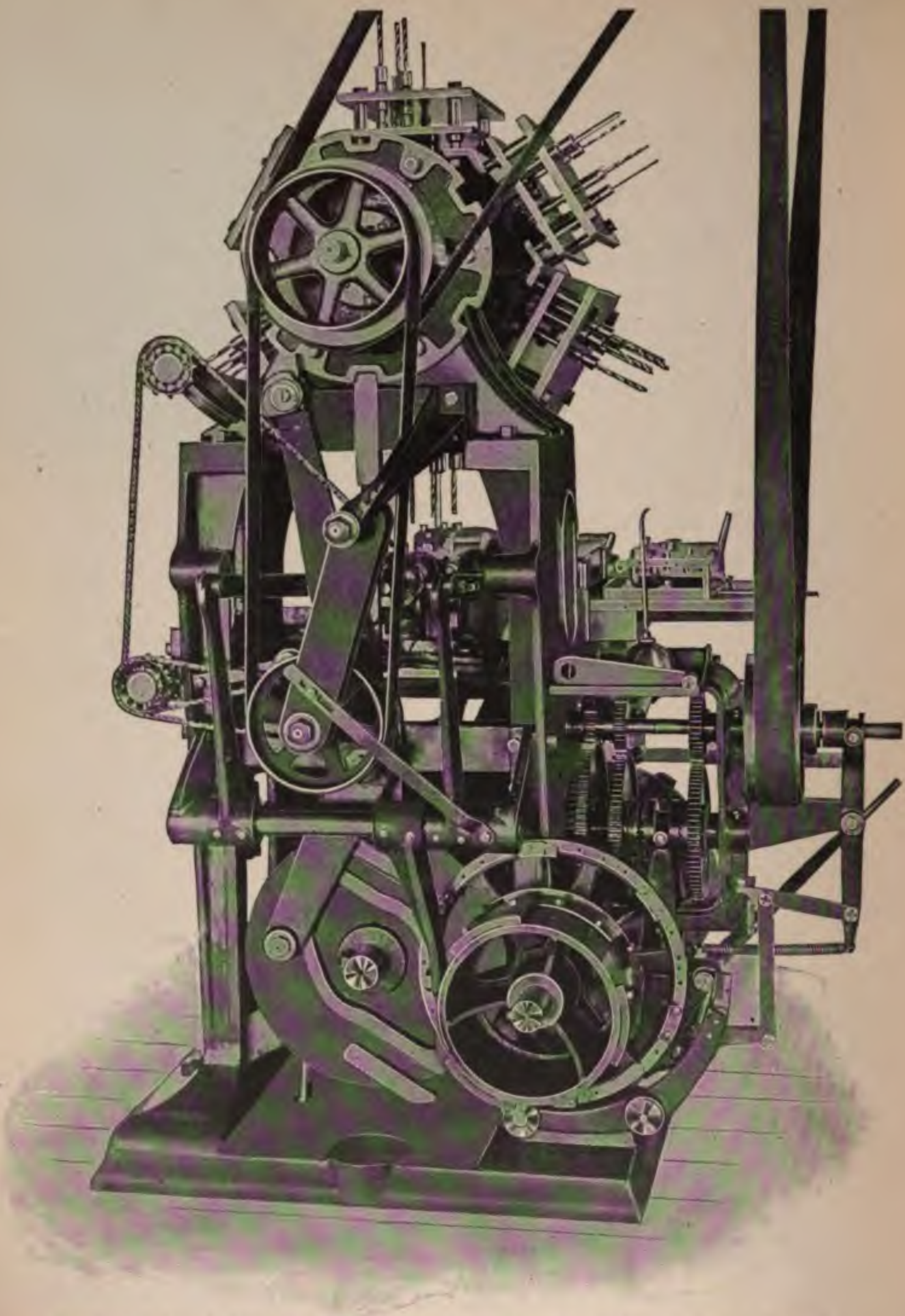
TRUE SECTION
DIAGRAM OF TRIANGLES
ELEVATION
PLAN
FULL PATTERN
A
B
C
G
E
F

## PLATE II.

This problem will give an examination on triangulation, being the development of an irregular solid whose bottom and top are round when viewed on horizontal planes, the top plane being cut off at an angle of 45° to the base line. First draw the base line 1′–6′, 2¾ inches long, placing the point 1′ 2 inches from the margin line, and the line 1′–6′ in the center of the sheet. Three inches above the bottom margin line draw the horizontal line 1′–6′ in plan; then with *a* as center and radius equal to one-half of 1′–6′ in elevation, draw the circle shown in its proper position below the line 1′–6′ in elevation. Now ¼ inch to the right of *a* on the line 1′–6′ in plan, establish *b*, which use as a center, and with 1⅜-inch radius describe the inner circle 1–3–6–*e*, which represents the upper horizontal plane of the irregular article. From the points 1 and 6 in plan, erect the vertical lines 1–1 and 6–6, making the height of the line 1–1 above the base line 1′–6′ in elevation 3¾ inches, and from the point 1 in elevation draw the line 1–6 at an angle of 45° intersecting the vertical line 6–6 at 6. Now draw lines from 1 to 1′ and from 6 to 6′, which completes the elevation.

Now divide the half plan into an equal number of parts (in this case 5) as shown by the small figures 1′ to 6′. In the same manner divide the inner circle into the same number of parts as shown from 1 to 6. Now draw solid lines from 1′ to 1, 2′ to 2, 3′ to 3, 4′ to 4, 5′ to 5, and 6′ to 6; and dotted lines from 1 to 2′, 2 to 3′, 3 to 4′, 4 to 5′, and 5 to 6′. From the intersections 1′ to 6′ on the outer plan, erect lines intersecting the base line in elevation from 1′ to 6′. In a similar manner, from the intersections on the inner curve in plan erect lines intersecting the top plane of he article from 1 to 6. Now connect lines in elevation from 2 to 2′, 3 to 3′, etc., although these lines are not necessary in the development of the pattern, but are given only to show their relationship to similar lines in plan. The solid and dotted lines in plan represent the bases of triangles, which will be constructed, whose altitudes are equal to similarly numbered vertical heights in elevation. The construction of these triangles is shown at B and C, B representing the triangles on solid lines in plan, and C the triangles on dotted lines in plan. Construct these triangles as follows: Extend the line 1′-6′ in elevation as E F, the point 6′ on E F to be placed 1 inch from the margin line. Now take the various distances of the dotted lines in plan as 6′ to 5, 5′ to 4, 4′ to 3, 3′ to 2, and 2′ to 1, and place them on the line E F as shown by similar numbers. Now from the small figures 1, 2, 3, 4, and 5 on the line E F, erect lines, which intersect by lines drawn from similarly numbered intersections on 1-6 in elevation, parallel to E F, thus obtaining the points 1°, 2°, 3°, 4°, and 5°. Then draw lines from 1° to 2′, 2° to 3′, 3° to 4′, 4° to 5′, and 5° to 6′, which will represent the diagram of triangles on dotted lines in plan, the slant lines representing the true lengths on the finished article. In precisely the same manner obtain the diagram of triangles B on solid lines in plan. For example, take the distance of 2-2′ in plan, and place it as shown by 2-2′ on the line E F; from 2 at right angles to E F draw the line 2-2° equal to the vertical height to 2 in elevation, and draw a line from 2° to 2′, which is the true length on 2-2′ in plan. It now becomes necessary to obtain a true section on the line 1-6 in elevation. Therefore at right angles to 1-6 and from the various intersections 1 to 6, draw lines as shown. Now measuring in each instance from the line 1′-6′ in plan, take the various distances to points 2, 3, 4, and 5, and place them in A on similarly numbered lines, measuring in each instance from the line 1-6 in elevation, thus obtaining the points 2″ to 5″. A line traced as shown will be the half section on 1-6 in elevation.

For the pattern proceed as follows: Draw any line as 1-1′ in G equal to 1-1′ in elevation. Now with radius equal to 1′-2′ in plan, and 1′ in G as center, describe the arc 2′. Then using 1 in G as center, and 1°-2′ in C as radius, intersect the arc 2′ in G. Now with radius equal to 1-2″ in the true section, and 1 in G as center, describe the arc 2, which intersect by an arc struck from 2′ as center and with 2°-2′ in B as radius. Proceed in this manner, using alternately as radii, first the divisions in the outer curve in plan, then the hypothenuses or slant lines in C; the divisions in the true section A, then the length of the slant lines in B, following the numbers in regular order until the last line 6-6′ in G is obtained, this line being obtained from 6-6′ in elevation.



NUTTING'S FULL AUTOMATIC UNIVERSAL MULTIPLE SPINDLE DRILL PRESS.

13,800 holes drilled every ten hours on this machine. This machine is fitted up for drilling sewing machine bed-plates. Three different kinds at one time.

National Automatic Tool Company.

# MECHANISM

The study of mechanism is the study of the laws that govern the motions and forces in machinery. Pure mechanism deals only with the amount and kind of motions, without regard to the forces transmitted, and in this instruction paper only this branch of the subject will be considered. That is, we shall study how to proportion the parts to get the proper motions. Knowing this, the principles of machine design and strength of materials will teach us how large the parts must be to stand the stresses which come upon them.

**A Mechanism** is a group of parts so shaped and arranged that a definite motion of one part will give other definite motions to the other parts.

**A Machine** is a combination of mechanisms each of which may be doing a different kind of work, but the whole combination of mechanisms working together accomplishes some desired result. Take for example, a metal planer; the result which is to be accomplished is the planing of a piece of metal, but in order to do this, several auxiliary results must be accomplished. The table or platen, to which the metal is fastened must be moved back and forth, the tool must be fed forward after each chip has been cut, and various other motions produced. There are certain pieces in the planer whose sole work is the moving of the platen, and all these pieces taken together form one mechanism; in like manner, there are certain parts whose sole work is feeding the tool forward each time, and all these parts taken together form another mechanism. All the mechanisms when brought together form the machine.

## MOTION.

An object which is changing its position is said to be in motion and an object which is not changing its position is at rest.

**Absolute and Relative Motion.** If a man is moving along in a sail boat without changing his position in the boat, both man and boat have what is usually spoken of as absolute motion, that is, they are both changing their position with respect to the earth and water around them. They both change their position in the same direction and at the same rate however, so that they are at rest with respect to each other. If now, the man should start to walk forward in the boat, he would change his position with respect to surrounding objects faster than the boat and he would have motion relative to the boat. We thus have two kinds of motion, absolute and relative; absolute motion being the motion of a body with respect to some fixed object, and relative motion being the motion of one moving body with respect to another moving body.

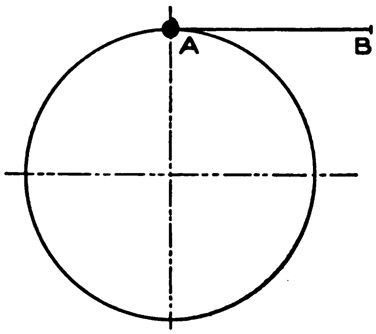



Fig. 1.

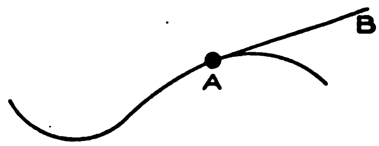



Fig. 2.

Since every object has more or less size and therefore can not be represented on paper as readily as can some particular point or line in the body, as far as possible in our study of the motions of bodies we shall consider points and lines, in place of the bodies themselves.

**Velocity** is the rate of motion. If a bullet travels through the air at the rate of one hundred feet in a second, it has a velocity of one hundred feet per second.

**Direction of Motion.** A point may have motion in a straight line, in a circle, or in any other curve. The tendency of any body which is in motion is to continue to move in a straight line unless caused to leave that path by some force applied to the body. The direction of the straight line in which a point is moving is called the direction of motion of the point. If an object is traveling in a circle, the direction of its motion at any given instant is the straight line tangent to the circle at the point where the object is at the given instant. For example, if the point A, Fig. 1, is moving around the circle, the direction of its motion, when in the position shown, is the line AB. In the same way in Fig. 2, if the point A is moving in the curved path, its direction when in the position indicated is the line AB.

By choosing a convenient scale, as one inch equals one foot, or one inch equals ten feet, etc., depending upon how large the velocities are with which we have to deal, the line may be drawn of a length that will represent the velocity of the point A. Suppose the circle, Fig. 1, to have a circumference of ten inches, and suppose the point A to be traveling around the circle at such a speed that it goes around once in five seconds; then, since it travels ten inches in five seconds, it has a velocity of two inches per second. Accordingly, if we draw the line AB two inches long, tangent to the circle at any given position of A, the line AB represents the direction and velocity of A at the instant under consideration. Of course, the direction of motion of a point which is moving in any path other than a straight line is constantly changing, but the direction in which it is moving at a given instant is the direction which it would take if the forces which constrain it to move in the curved path were removed at that instant.

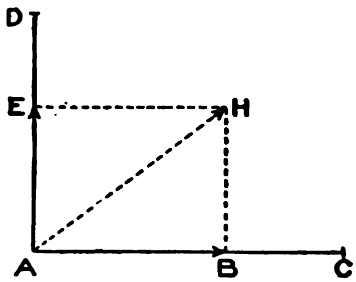


Fig. 3.

**Composite Motions.** In Fig. 3, let A represent a body lying on a table; suppose AC and AD are strings making a right angle with each other. First, let the string AC be pulled with such force that it will cause A to move one inch in the direction AC, in one second; then A will be at B at the end of a second, the line AB representing the direction and velocity of A when the string AC is pulled. Next, suppose the body to be back in its original position A, and that the string AD is pulled with such force that it will cause A to move $\frac{3}{4}$ of an inch in the direction AD in one second; then at the end of a second A will be at E, the line AE representing the direction and velocity of the body when the string AD is pulled.

Again, suppose both strings to be pulled at the same time, with the same force as before. Then the pull on AC will still cause A to move toward C with a velocity AB, and the pull on AD will cause A to move toward D with a velocity AE, so that at the end of a second the body will be at neither E nor B, but at some point H, whose position is at a distance BH from B, the line BH being equal and parallel to AE. The point H is also at a distance EH from E, the line EH being equal and parallel to AB. In other words, the path over which the body has moved is the line AH, which is the diagonal of a parallelogram whose sides are equal to AB and AE respectively. The lines AB and AE, which represent the velocities caused by the pulls on the respective strings, must be drawn to the same scale, that is, if the pull on AC causes a velocity of one inch per second and

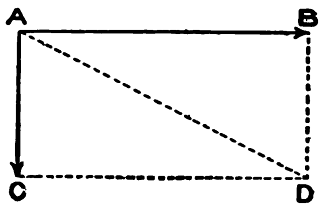



Fig. 4.

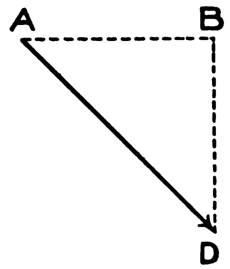



Fig. 5.

the pull on AD causes a velocity of $\frac{3}{4}$ inch per second, AE must be $\frac{3}{4}$ as long as AB.

The velocities AB and AE are called *component velocities*, and the velocity AH the *resultant*.

Let us take another example. Suppose a ball is thrown toward the east with a velocity of ten feet per second, and the wind carries the ball toward the south with a velocity of five feet per second. Let us find graphically how fast and in what direction the ball is actually moving. Using any convenient scale, draw the line AB, Fig. 4, to represent ten feet, and the line AC to represent five feet at the same scale, AC being at right angles to AB, since south is at right angles to east. From C draw CD parallel to AB, and from B draw BD parallel to AC meeting CD at D; then AD, the diagonal of the rectangle thus formed, gives the direction and the velocity, at the same scale as before, of the actual motion of the ball.

The preceding process is called *composition* of velocities; that is, if we know the velocity of a body in two directions at right angles to each other, we can find from these the real velocity and direction of the motion. Quite as frequently we have given the real direction and velocity and wish to find the velocity parallel and at right angles to some given line. Thus, suppose we know that a ball is moving at a speed of one hundred feet per minute toward the southeast and we wish to know how fast it is moving towards the east. Draw the line AD, Fig. 5, to represent one hundred feet, at a convenient scale; then draw the line AB, making with AD the same angle that a line running southeast makes with a line running east (that is, 45 degrees). From D draw DB perpendicular to AB, meeting AB at B; the length of AB represents, at the same scale at which AD was drawn, the velocity of the ball in an easterly direction, and BD represents its velocity in a southern direction. This is called the *resolution* of velocities, the velocity AD being resolved into two components, one in the direction AB, and one perpendicular to this direction.

## *EXAMPLES FOR PRACTICE.

1. If a steamer travels 91,200 feet per hour, what is the velocity in feet per second?

Ans. 25.33 feet.

2. If the piston of an engine moves at the rate of 12.5 feet per second, what is the piston speed in feet per minute?

Ans. 750 feet.

3. A steamer is moving eastward at a speed of 800 feet per minute and the wind and tide carry it north at the rate of 100 feet per minute. Find graphically how fast and in what direction the steamer is actually moving.

Ans. 810 feet per minute.

4. A ball is thrown, with a velocity of 50 feet per second, across a stream 100 feet wide. The wind carries the ball up stream 10 feet per second. How far up stream from the point at which the ball was aimed will it strike? Ans. 20 feet.

*NOTE. To be solved graphically.

**5.** A platform is set up at an angle of 30 degrees with the horizontal, and a weight is allowed to slide down the platform at a speed of ten feet per second. How long will it take the weight to get 10 feet below the point from which it started?

Ans. 2 seconds.

**6.** The horizontal component of the velocity of a body is 26 feet per minute. If the actual velocity is 52 feet per minute find graphically the vertical component.

Ans. 45 feet per minute (about).

**7.** A man is on a railway train which is moving at the rate of 25 miles per hour and walks toward the rear of the train at the rate of 88 feet per minute. How fast is the man actually moving?

Ans. 24 miles per hour.

**Temporary Center of Revolution.** In Fig. 6, let AB represent a bar that forms some part of a mechanism, and suppose that for the moment the end B has a velocity in the direction of and equal to BD, and that the end A has a velocity in the direction of and equal to AC. As the whole rod, for the instant, is moving as if it were revolving about a center, the actual velocities of the various points in the rod are proportional to their distances from the center. To find the center for the case shown, draw the lines AT and BT perpendicular to AC and BD, respectively, until they meet at T, which is the center about which the whole rod may be considered to be revolving. The velocities AC and BD cannot be chosen at random, but must be such that BF is equal to AE; that is, their components in the direction of AB must be equal.

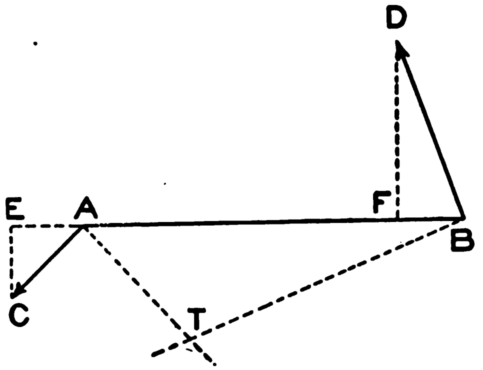


Fig. 6.

## REVOLVING BODIES.

One of the most common motions which is found in machinery of all kinds is the motion of revolution, that is, the motion of a body turning around a center or axis. The axis may pass through the body itself or it may lie entirely outside the body. Fig. 7 is an example of the first case, where the cylinder is revolving about the shaft A, which passes through the center of the cylinder. Fig. 8 is an example of the second case where the block B is revolving about the shaft A.

The speed of revolution of a body is generally described by giving its number of revolutions per minute, which is abbreviated to R. P. M.

We will use the following abbreviations throughout this instruction paper: $d$=diameter; $r$=radius or distance of a point from the center about which it is revolving, and $\pi$ (pronounced Pi)=3.1416.

Let us consider a point C on the circumference of the cylinder in Fig. 7. For every complete revolution of the cylinder the

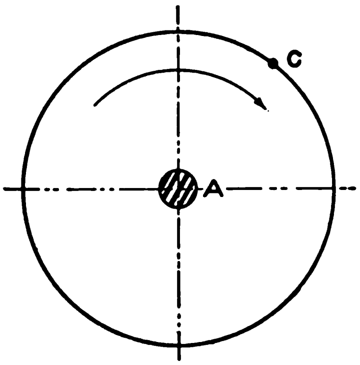



Fig. 7.

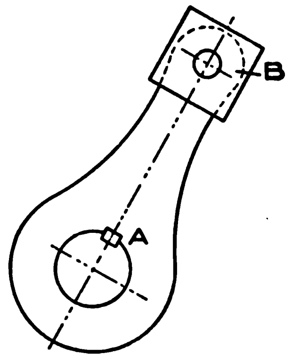



Fig 8.

point C travels through the air a distance equal to the circumference of the cylinder, or, since the circumference of a cylinder is 3.1416 times its diameter, the point C will travel 3.1416 times the diameter of the cylinder. Therefore the actual velocity through the air or **linear velocity** as it is termed, of a point on the circumference of a revolving cylinder is equal to the diameter of cylinder times 3.1416 times the number of revolutions in a unit of time.

If we assume a foot as our unit of distance and a minute as our unit of time, the above principle may be stated as a formula:

$$\text{Linear Velocity} = \pi\, d \text{ times R. P. M.} \qquad (1)$$

$$\text{or `` `` } = 2\,\pi\, r \text{ times R. P. M.} \qquad (2)$$

This will give the linear velocity in feet per minute and to use this formula the diameter or radius must be expressed in feet or fractions of a foot. If $d$ or $r$ is in inches, the linear velocity will be in inches. If linear velocity per second is desired, the number of revolutions per second must be used instead of R. P. M. From this formula we see that the linear velocity varies directly as the diameter or radius, and also directly as the number of revolutions.

The following examples will illustrate the use of the above formula:

If a fly wheel is 10 feet in diameter and makes 75 revolutions per minute, how fast is a point on its circumference moving? Using formula (1),

$$\begin{aligned} \text{Linear Velocity} &= \pi\, d \times \text{R. P. M.} \\ &= 3.1416 \times 10 \times 75. \\ &= 2356.2 \text{ feet per minute.} \end{aligned}$$

Therefore a point on the circumference of the fly wheel is moving at the rate of 2356.2 feet per minute.

Suppose that the center of the block B, Fig. 8, is at a distance of 18 inches from the center of the shaft A and that the arm turns around the shaft 60 times per minute. To find the linear velocity of the center of block B, we must first reduce the 18 inches to feet. Then,

$$\begin{aligned} \text{Linear Velocity} &= 2 \times 3.1416 \times 1.5 \times 60. \\ &= 565.49 \text{ feet per minute.} \end{aligned}$$

The same formula may be used to find the diameter or radius when the linear velocity and revolutions are given, or to find the revolutions when the linear velocity and diameter or radius are given. To do this, substitute the known quantities in the equation and solve by Algebra to find the unknown quantity. Let V = Linear Velocity.

**Linear Velocity:** $V = \pi d \times R.P.M.$

**Diameter:** $d = \dfrac{V}{\pi \times R.P.M.}$

**Revolutions:** $R.P.M. = \dfrac{V}{\pi d.}$

## EXAMPLES FOR PRACTICE.

1. Find the linear velocity of a point on the rim of a fly wheel making 120 revolutions per minute. Assume fly wheel to be 7 feet in diameter. Ans. 2638.9 feet.

2. How many turns will a 6-foot wheel make while going one mile?

Ans. 280.

3. A locomotive is running at the rate of 40 miles per hour. How many revolutions are the $6\frac{1}{2}$-foot drivers making per minute? Ans. 172.

4. The drivers of a locomotive are $5\frac{1}{2}$ feet in diameter. The crank pin is twelve inches from the center of the wheel. Find the linear velocity in feet per second of the crank pin if the engine makes 25 miles per hour. Ans. 13.32.

## CYLINDERS AND CONES REVOLVING IN CONTACT.

When two cylinders are arranged to revolve upon parallel axes which are at a distance apart just equal to the sum of the radii of the two cylinders, their circumferences will touch along one line, and if both cylinders revolve and we assume that there is no slipping of one surface on the other, the surface velocities of their circumferences must be equal, that is, the linear velocity of any point on the surface of one would be the same as the linear velocity of any point on the surface of the other. Then, if in Fig. 9, we let S equal the surface velocity of the cylinders, C the radius of cylinder A, D the radius of B, M the revolutions per minute of A, and N the revolutions per minute of B, we can obtain the following equations by substituting these values in formula (2):—

$$S = 2 \pi C \times M.$$
$$S = 2 \pi D \times N.$$

and dividing the first by the second we have:

$$\frac{S}{S} = \frac{2\pi C \times M}{2\pi D \times N} \text{ or } 1 = \frac{C M}{D N}$$

therefore $D N = C M$ or $D \times N = C \times M$.

According to ratio and proportion in Algebra,

$$\frac{M}{N} = \frac{D}{C} \qquad (3)$$

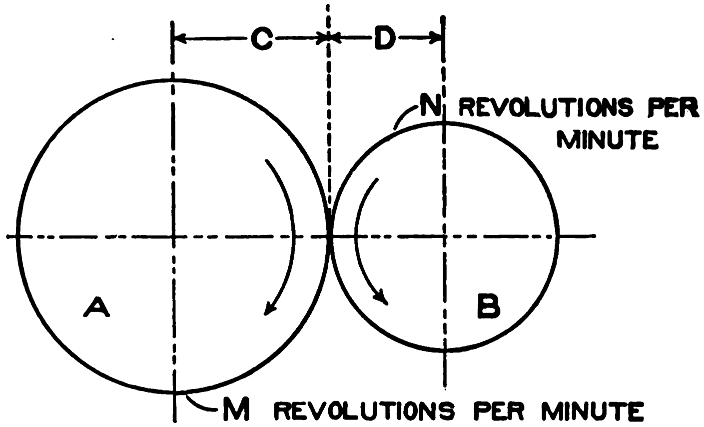



Fig. 9.

This may be stated as follows:—

$$\frac{\text{Revolutions of Driver}}{\text{Revolutions of Driven}} = \frac{\text{Radius of Driven}}{\text{Radius of Driver}}$$

That is, the numbers of revolutions are to each other inversely as the radii, and therefore as the diameters.

Two cylinders revolving in contact, without slipping, revolve in opposite directions; that is, if A revolves right-handed (like the hands of a clock), B will revolve left-handed. This is indicated by the arrows in Fig. 9.

The following examples will illustrate the method of calculation for speeds of cylinders, according to the preceeding discussion. Suppose a wheel A, 2 feet in diameter, is revolving with its surface in contact with the surface of another wheel B. A makes

25 R. P. M. Assuming that no slipping occurs between the surfaces of the two wheels, what must be the diameter of B in order that it shall make 75 R. P. M.? From the formula (3) we have

$$\frac{\text{Diameter of B}}{\text{Diameter of A}} = \frac{\text{R. P. M. of A}}{\text{R. P. M. of B}}$$

or

$$\frac{\text{Diameter of B}}{\text{2 feet}} = \frac{25}{75}$$

$$\text{Diameter of B} \times 75 = 2 \times 25$$

therefore Diameter of B $= \frac{2}{3}$ feet $= 8$ inches.

The same principles apply to cones which are revolving in contact. Let Fig. 10 represent the side view of two right cones which are in contact along the line EF, which is an element common to both. Then,

$$\frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{\text{F G}}{\text{F H}} \quad (4$$

That is, their revolutions are to each other inversely as the diameters of their bases. If the angles OEF and O′EF are known, instead of the diameters of the bases, the ratio of the number of revolutions may be found from the following trigonometric formula:

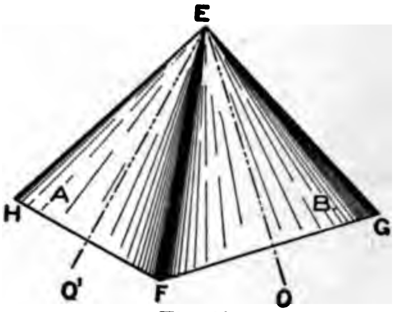


Fig. 10.

$$\frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{\text{Sine of angle OEF}}{\text{Sine of angle O'EF}} \quad (5)$$

If the angle between the axes OE and O′E is given and it is desired to find the relative sizes of the two cones whose revolutions shall have a given ratio, the angles OEF and O′EF could be calculated, but the calculation would be rather difficult and therefore a solution which is partly graphical is more convenient and usually sufficiently accurate.

Let EO′ and EO Fig. 11, be the center lines of two shafts which lie in the same plane and make an angle of 45 degrees with each other. The shafts are to be connected by two rolling cones so that the shaft O'E shall make 30 revolutions while the shaft OE makes 40. The base of the larger cone is 12 inches, to find the base of the smaller cone and the altitude of both. Since, from the preceding discussion, the speeds are inversely as the diameters of the cones, the larger cone must be on the shaft which is making the fewer number of revolutions, that is, O'E.

Then from formula (4).

$$\frac{\text{Speed of O'E}}{\text{Speed of O E}} = \frac{\text{Diameter of base of cone on O E}}{\text{Diameter of base of cone on O'E}}$$

$$\tfrac{3}{4} = \frac{\text{Diameter of base of cone on OE}}{12}$$

Solving the equation we get

Diameter of base of cone OE = 9 inches.

Now draw the line PN parallel to O'E and at a distance from O'E equal to the radius of the base of the cone O'E (in this case 6 inches), at a convenient scale, and draw the line ML parallel to OE and at a distance equal to the radius of the base of the cone on OE (in this case $4\frac{1}{2}$ inches). These lines intersect at the point C. A line from C to E is the element along which the cones touch each other. From C draw lines perpendicular to OE and O'E, meeting them at S and R respectively. Then SE and RE are the altitudes. To draw the cones, lay off ST equal to CS, and RV equal to CR. Join E with T and V and the cones are complete.

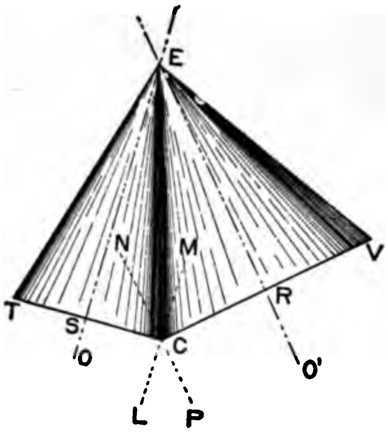


Fig. 11.

## CYLINDERS AND CONES CONNECTED BY BELTS.

Frequently two shafts must be connected so that one may drive the other, and yet they are so far apart that cylinders cannot be placed on them which will touch each other. In this case it is customary to place on each shaft a cylinder, or pulley, and over

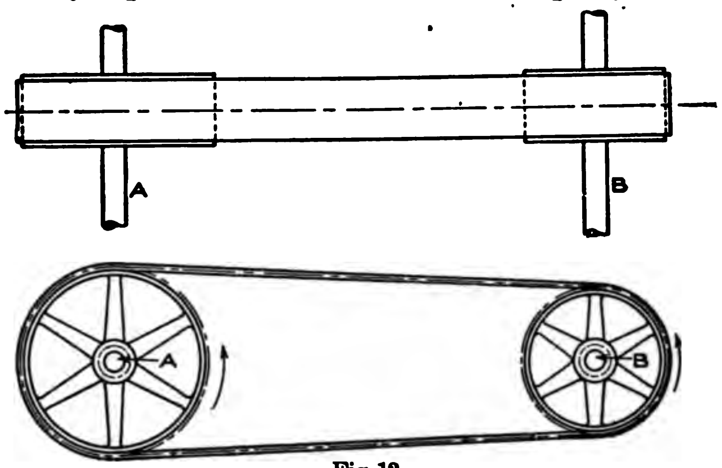



Fig 12.

these pulleys stretch a band, or belt made of some flexible material. The pulleys are fastened to the shafts so that the pulley and its shaft turn together, and the belt is stretched over the pulleys tight enough so that the friction between the belt and the surface

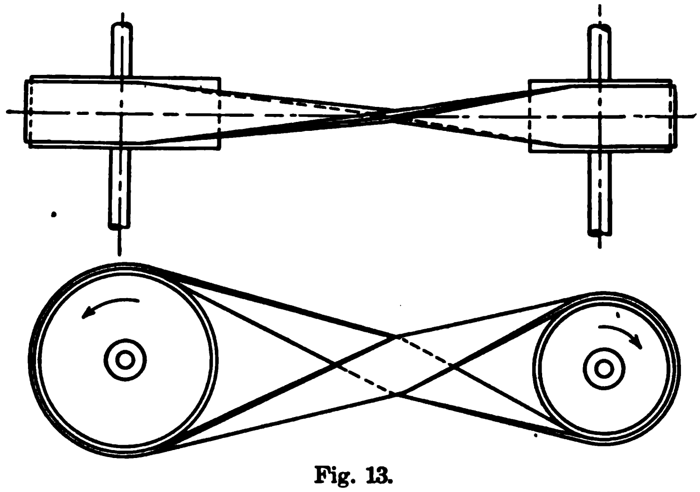


Fig. 13.

of the pulley is sufficient to make them travel with the same linear velocity. A detailed study of the exact manner of finding the proper locations of the pulleys and drawing the pulleys and belts can be found in Mechanical Drawing Part V, so that we will now study only the general principles involved, particularly with reference to making the necessary calculations.

The principles which we learned above, concerning the relative speeds of two cylinders in contact, apply also to two pulleys connected by a belt. The rule governing the direction of rotation, however, is different. When the connection is made by means of a belt, the relation of the directions of rotation depends upon the way the belt is put around the pulleys. If the belt is put on as shown in Fig. 12, known as open belt, the pulleys will turn in the

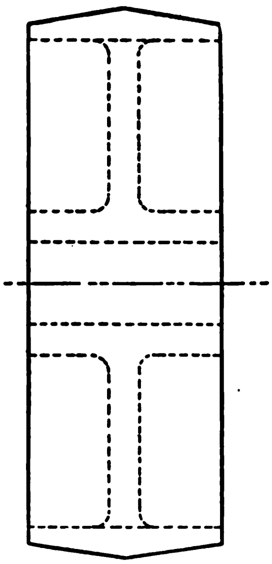


Fig. 14.

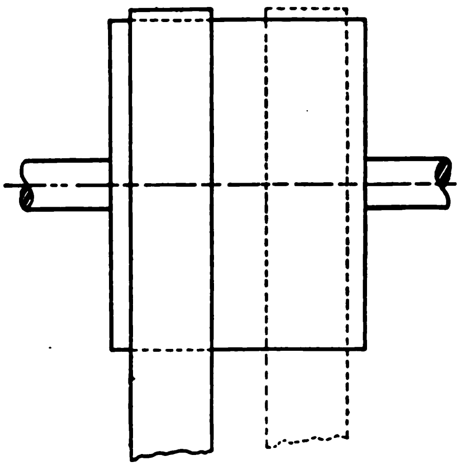


Fig. 15.

same direction. If the belt is as shown in Fig. 13, known as a crossed belt, the pulleys will turn in opposite directions.

**Crowning Pulleys.** The outer surface of pulleys, instead of being made cylindrical is often made of larger diameter in the middle, as shown in Fig. 14. A pulley having this increase of diameter in the middle is said to have a crowned face. The object of the crowning is to help the belt to remain on the pulley. A belt will always run to the part of the pulley which is largest in diameter; therefore, if the diameter increases towards the middle, the belt will tend to run to the middle, and will be less likely to slip off. If the belt is to be at different places on the pulley at different times, as indicated by the full and dotted positions in Fig. 15, the surface cannot be crowned, but must be cylindrical.

As problems similar to the following often arise, this one should be studied carefully until every step is understood. In Fig. 16, A is a shaft turning 60 R. P. M. in the direction indicated by the arrow. B and C are cylinders over which a strand of cloth is to pass as indicated, the cloth passing over the top of B and under the bottom of C. In order that B and C may revolve in proper direction a crossed belt must be used between A and C,

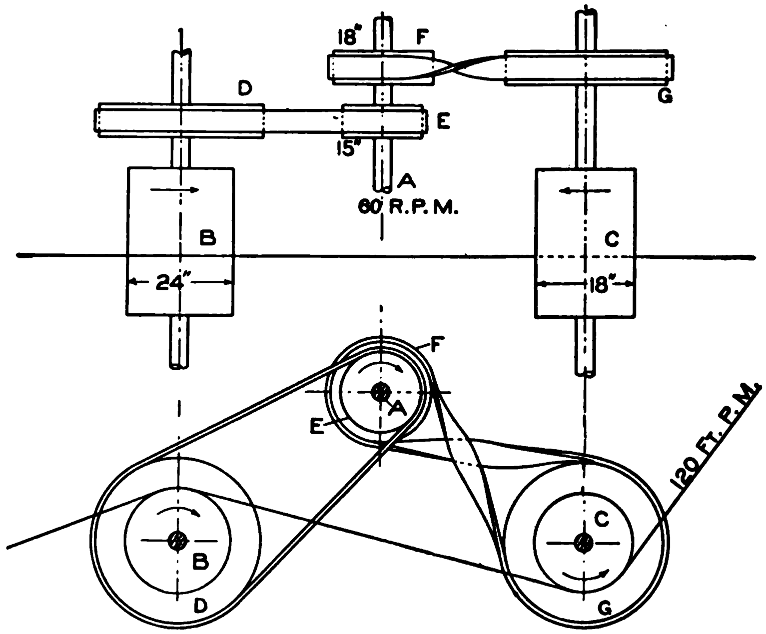



Fig. 16.

as shown. B is 24 inches in diameter, C is 18 inches in diameter, and the cloth is to travel at the rate of 120 feet per minute. E is a pulley 15 inches in diameter, which drives the pulley D, on the same shaft as B. F is a pulley 18 inches in diameter, driving pulley, G, on the same shaft as C. The problem is to find the number of revolutions of B and C, and the diameters of D and G.

The circumference of B = 24 inches $\times \pi =$ 2 feet $\times \pi =$ 6.2832 feet. Therefore, its surface velocity if it made one R. P. M. would be 6.2832 feet per minute. But since it is to have a surface velocity $= 120$ feet per minute (equal to that of the cloth) its speed must be 120 divided by $6.2832 = 19.1$ R. P. M. Revolutions of C are found in the same way.

18 inches $= 1.5$ feet. 1.5 feet $\times\ 3.1416 = 4.7124$ feet $=$ surface speed.

120 divided by $4.7124 = 25.4$ R. P. M.

Now from formula (3):

$$\frac{\text{Revs. of D}}{\text{Revs. of E}} = \frac{\text{Diameter of E}}{\text{Diameter of D}}$$

and since the revolutions of D $=$ the revolutions of B

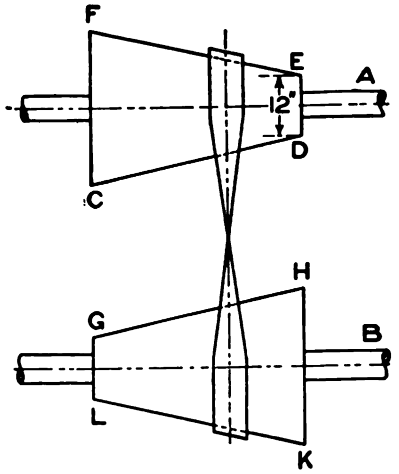


Fig. 17.

$$\frac{19.1}{60} = \frac{15}{x}$$

$$19.1\,x = 15 \times 60$$

$$x = 47.12 +$$

therefore, pulley D is $47\frac{1}{8}$ inches in diameter.

$$\frac{\text{Revs. of G}}{\text{Revs. of F}} = \frac{\text{Diameter of F}}{\text{Diameter of G}}$$

$$\frac{25.4}{60} = \frac{18}{x}$$

$$25.4\,x = 18 \times 60$$

$$x = 42.5 \text{ (approx.)}$$

therefore, pulley G is 42.5 inches in diameter.

**Taper Cones.** Suppose two equal frustums of cones are arranged on parallel shafts, as shown in Fig. 17. Shaft A, turning at a constant speed, can be made to drive shaft B at different speeds by changing the location of the belt on the cones. In order to use cones with a straight taper, a crossed belt should be used. If an open belt is used, the cones should be shaped as shown in Fig. 18. It is necessary to give this curvature to the face in order to keep the same tension on the belt for different positions. With a crossed belt this condition is fulfilled by making the face a straight line. If the shafts are far apart, the straight cones are sometimes used for an open belt.

Since the calculations for finding the proper shape of the cones for an open belt are difficult and are not often needed, we will give our attention only to the straight cones for a crossed belt.

In Fig. 17 let shaft A be the driver, turning at a constant speed of 100 R. P. M. The small end of the cone on A is 12 inches in diameter. We wish to find the diameter of the large end of the cone on B, in order that the slowest speed of B may be 75 R. P. M. Then, if the cones are alike, to find the greatest speed of B:

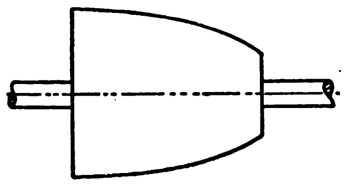


Fig. 18.

First $$\frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{HK}{ED}$$

$$\frac{100}{75} = \frac{HK}{12}$$

$$75\ HK = 12 \times 100$$

Therefore $H\,K = \frac{1200}{75} = 16$ inches.

Now, if the cones are equal

and $$G\,L = E\,D = 12$$
$$F\,C = H\,K = 16.$$

Then $$\frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{G\,L}{F\,C}$$

$$\frac{100}{x} = \frac{12}{16}$$

$$x = \frac{1600}{12} = 133\tfrac{1}{3}.$$

Therefore, the larger ends of the cones must be 16 inches in diameter and B will have a variation of speed from 75 R. P. M. to $133\frac{1}{3}$ R. P. M. The length of the cone does not affect the extreme speeds, but the longer the cones the more easily the intermediate speeds may be obtained.

Cones arranged as explained above are used to drive drying machines in bleacheries and similar places, where it is desired to vary the speed af the machine according to the weight of the cloth which is being dried. Heavy cloth requires a longer time to dry than light cloth and consequently can not be passed through the machine as rapidly. Tapered cones are also found in various cotton machines.

**Stepped Cones.** Stepped cones are often used in place of the tapered cones. These are really a series of pulleys side by side on a shaft, a similar series being placed on the other shaft with the large pulley on the second shaft in line with the small pulley on the first shaft. The arrangement is shown in Fig. 19. In practice the several pulleys which make up the stepped cones are cast together, both cones usually being cast from one pattern. The cal-

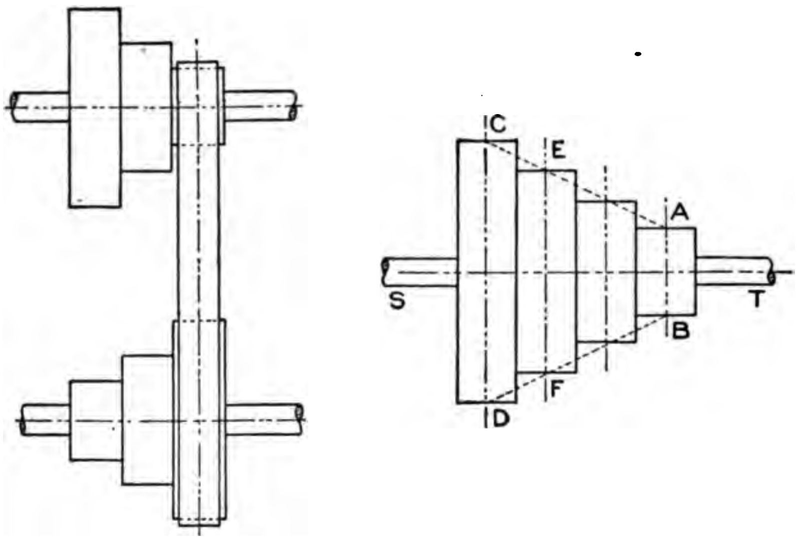



Fig. 19.

culation for the diameters of the end steps are the same as for the end diameters for the cones (Fig. 17). Assuming that both cones are alike, the intermediate steps can be found as follows:—

Decide how many intermediate steps are desired, then draw the center line ST, and draw the lines AB and CD perpendicular to ST and at a distance apart equal to the width of face of one step multiplied by the whole number of steps minus one. Make CD equal in length to the diameter of the largest step and AB equal to the diameter of the smallest step. Draw AC and BD. Draw EF parallel to and at a distance from CD equal to the width of the face of one step. The distance between E and F, the points where EF intersects AC and BD, will be the diameter of the second step. Other steps may be found in the same manner. To use this method all steps must have the same width of face. It would not be accurate for an open belt, although if the distance between the shafts are large compared with the diameter of the cones, an open belt might not give trouble on cones designed in this way.

Stepped cones are very commonly used for driving lathes and other machine tools.

### EXAMPLES FOR PRACTICE.

1. A shaft making 115 revolutions per minute has keyed to it a pulley 36 inches in diameter. If the pulley belted to the 36-inch pulley is 26 inches in diameter, how many revolutions will it make per minute?

Ans. 160 revolutions. (nearly.)

2. A pulley 12 inches in diameter makes 180 revolutions per minute. The other pulley connected by belt to the 12-inch pulley should make 75 revolutions. How large must it be?

Ans. 28.8 inches in diameter.

3. A motor shaft having a pulley 6 inches in diameter makes 840 revolutions. If this speed is to be reduced to 320 revolutions, what size pulley should be used?

Ans. $15\frac{3}{4}$ inches in diameter.

**Disk and Roller.** Fig. 20 shows a device by means of which one shaft turning always in the same direction with a constant speed may drive another shaft, which is at right angles to it, in either direction and at different speeds. A is a disk on the end of the overhanging shaft S. On the shaft T is placed a roller B free to be moved up or down on T, but on a key so that it must turn with the shaft. Some sort of a shipper must be provided to hold B in the desired position on T. When one shaft turns it drives the other by means of the friction between A and B. If shaft S is the driver, turning in the direction indicated by the arrow, it will cause T to turn in the direction indicated by the lower arrow. If it is desired to have T turn in the opposite direction, keeping the direction of S the same, B must be moved up above the center line of S as shown dotted. If OR is the distance from the center of disk A to the point where the center line of the face of B strikes

A, and LR is the radius of B, we have the following equation,—

$$\frac{\text{R. P. M. of B}}{\text{R. P. M. of A}} = \frac{\text{O R}}{\text{L R}} \qquad (6)$$

from which, knowing the speed of one, the speed of the other may be calculated. It will be seen from this equation that if OR is decreased, that is, if B is moved nearer the center line of S, the speed of B will decrease if A is the driver, or the speed of A will increase if B is the driver.

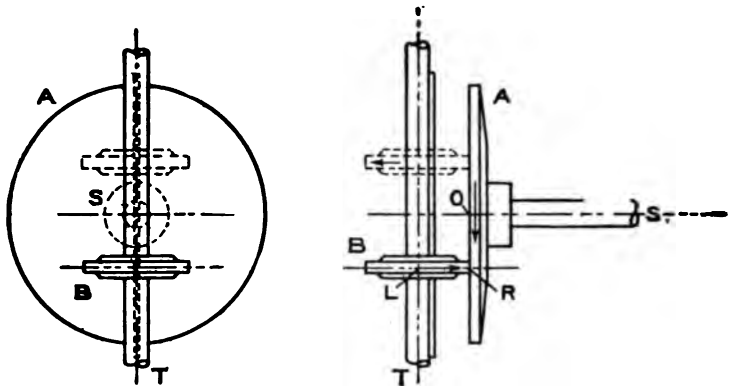



Fig. 20.

This device is used for driving drying machines where the cloth goes from another machine direct to the drying machine, and it is essential that the speed of the two should be adjusted to a nicety, in order that excessive strain may not come upon the cloth. It is also used for driving the feed mechanism on machine tools, particularly drills.

Example: Suppose the disk A makes 70 revolutions per minute and disk B 124 revolutions. If OR is 18 inches what is the diameter of B?

$$\frac{\text{R. P. M. of B}}{\text{R. P. M. of A}} = \frac{\text{O R}}{\text{O L}} \text{ or } \frac{124}{70} = \frac{18}{\text{OL}}$$

$$124 \times \text{O L} = 70 \times 18$$

$$\text{O L} = \frac{70 \times 18}{124}$$

$$= 10.16 \text{ inches (about).}$$

Diameter would be $2 \times 10.16 = 20.32$ inches or $20\frac{5}{16}$ inches.

## EXAMPLE FOR PRACTICE.

1. Disc B, Fig. 20, is 12 inches in diameter and makes 280 revolutions per minute. If shaft S is to make 48 revolutions per minute how far from the center must the circumference of B be placed? Ans. 35 inches.

## DISCONNECTING AND REVERSING MECHANISMS.

**Tight and Loose Pulleys.** Fig. 21 shows a very common arrangement of pulleys, whereby the shaft A may be stopped while the driving shaft B continues to run. Pulley C is keyed to

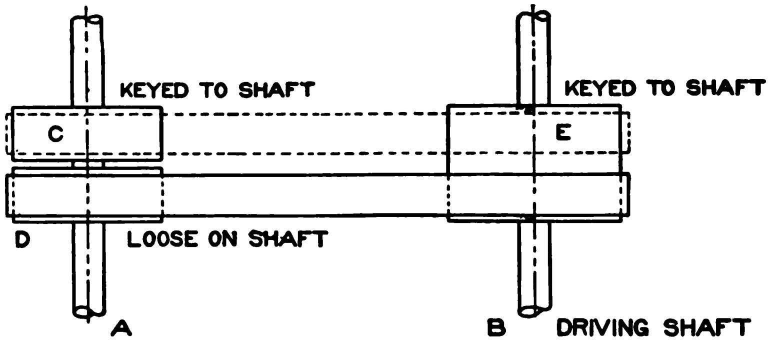



Fig. 21.

shaft A, while pulley D is free to run on A. Pulley E has its face equal in width to the sum of the other two and is keyed to B. When the belt is in the position shown in full lines, D turns with E, while shaft A remains at rest. The belt is guided by a shipper and when it is desired to start A, the belt is moved into the position shown by the dotted lines.

**Jaw Clutch.** Fig. 22 illustrates an arrangement by which the gear, or pulley, A may be attached to turn with the shaft, or disconnected so as to turn independently of the shaft. The hub of A has jaws or teeth on its end, and the sliding piece B has similar teeth, the projections on B fitting into the indentations of A. The shaft may turn freely in A while B slides on a key so that it must turn with the shaft. When B is in the position shown, the shaft and A may turn independently of each other, but when B is moved to the left so that its teeth engage with the teeth on the hub of A, it serves to clamp A to the shaft. The principle here involved is used in many different forms of clutches.

**Friction Clutches.** A jaw clutch such as illustrated in Fig. 22, if thrown in while the shaft or gear is turning brings a sudden shock on the parts, which is likely to cause damage, especially if the speed is high and much power is transmitted. Consequently, a clutch known as a friction clutch is often used, which, as its action depends upon the friction between two parts, will impart motion more gradually thereby avoiding the shock. Fig. 23 illustrates a simple clutch of this kind. B is a piece free to slide on a key, and held in position by a shipper. A is a pulley or gear loose on the shaft. The outer surface of B and the inner surface of A are tapered to fit each other. When B is thrown to the left it clamps A to the shaft in the same manner as the jaw clutch.

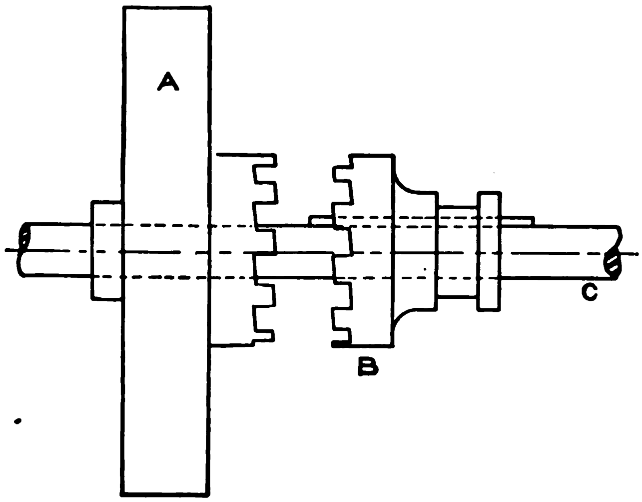



Fig. 22.

**Two Clutches for Reversing.** Fig. 24 shows how two clutches can be arranged so that either one may be thrown in, thus giving motion to the shaft in either direction. The clutches are similar in principle to the one shown in Fig. 23. The left-hand clutch is shown partly cross-sectioned. The piece A is attached to a shipper which when moved to the right throws in the right-hand clutch; when moved to the left throws in the left-hand clutch. If the pulley of the right-hand clutch is driven by an open belt and the pulley of the left-hand clutch by a crossed belt, the shaft will be driven

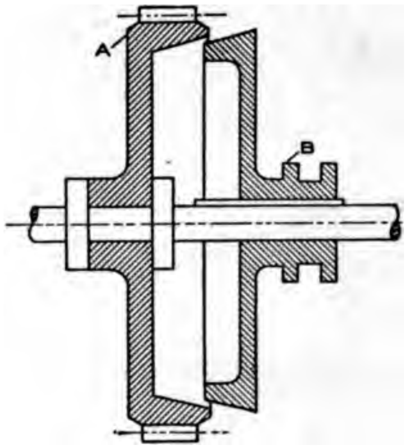



Fig. 23.

in either direction according as one or the other clutch is thrown in. When A is in the position shown neither clutch is in and the shaft is at rest.

## SCREWS.

**The Helix.** Since all screws depend upon a curve known as

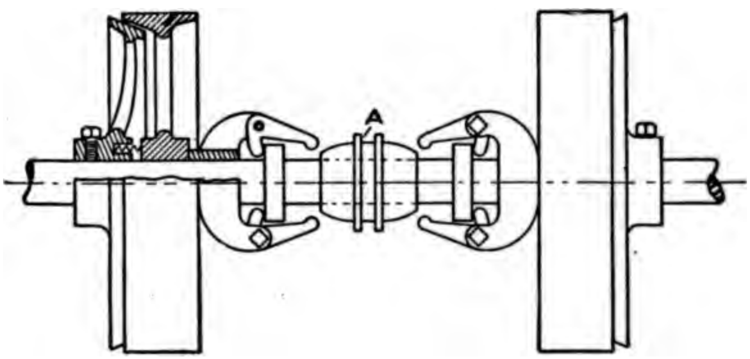



Fig. 24.

the helix, it will be necessary to understand something about this curve before attempting the study of the screw.

Take a cylindrical piece of wood, such as is shown in Fig. 25, and a rectangular piece of paper, ABFE, with the side AB equal to the circumference of the cylinder, and the side AE equal to the length of the cylinder. Now, if we lay off along AE a distance

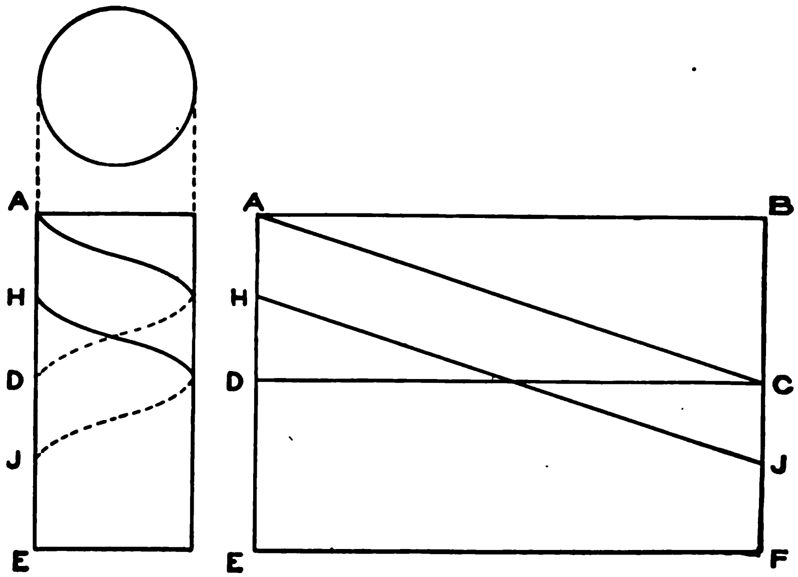



Fig. 25.

AD, and draw the line DC parallel to AB, we have the rectangle, ABCD. Now draw the diagonal, AC, of the rectangle and wrap the paper around the cylinder, keeping the side AE on an element of the cylinder; the paper will just cover the cylinder, the edge

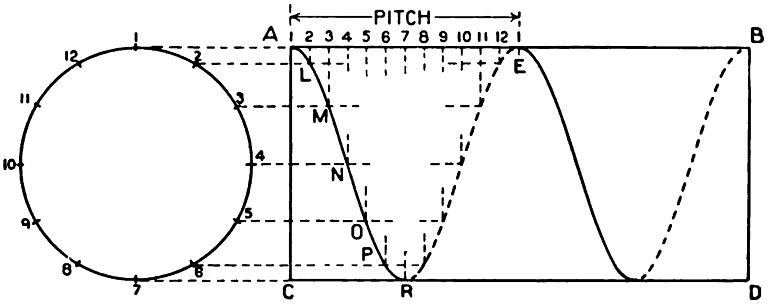



Fig. 26.

BF meeting the edge AE. The point C will coincide with D and lie on the same element of the cylinder as A and at a distance from A equal to AD. The shape which the line AC now takes is called a helix, and the distance AD is called the pitch of the helix. If we choose another point, H, half-way between A and D, and draw a line HJ parallel to AC, this line when wrapped around the cylinder will form another helix of the same pitch as the first one. The two together form what may be called a double helix. If the line AD is divided into three equal parts instead of two, and lines

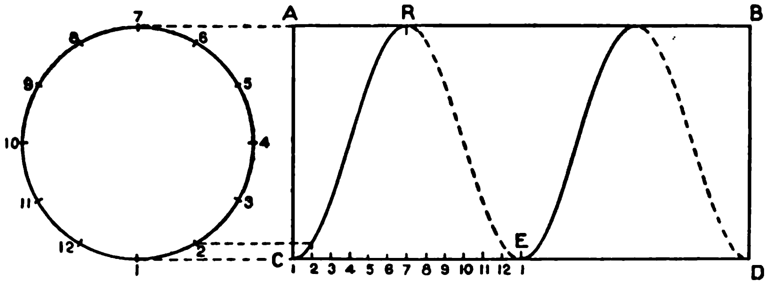



Fig. 27.

parallel to AC be drawn from each of the points of division, we would have on the cylinder three parallel and equidistant helices of the same pitch, or a triple helix. Fig. 26 shows a single right-hand helix, Fig. 27 a single left-hand helix, Fig. 28 a double right-hand helix, and Fig. 29 a triple right-hand helix.

If a helical groove is cut on the surface of a cylinder, a screw

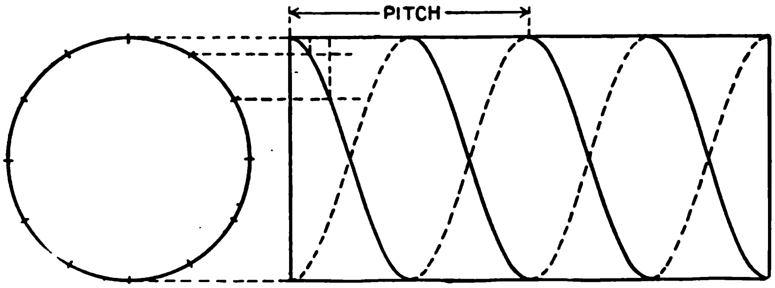



Fig. 28.

thread is formed, the thread being the material which is left between the successive turns of the helical groove. A cylinder having a thread on it is called a screw, and a piece having a cylindrical hole in it, with a thread around the hole, is called a nut. The groove which is cut to form the thread may be in the form of a single, double or triple helix, and either right-hand or left-hand; the thread would be described in the same terms.

Fig. 30 shows a right-hand and a left-hand single V thread and a right-hand and a left-hand single square thread.

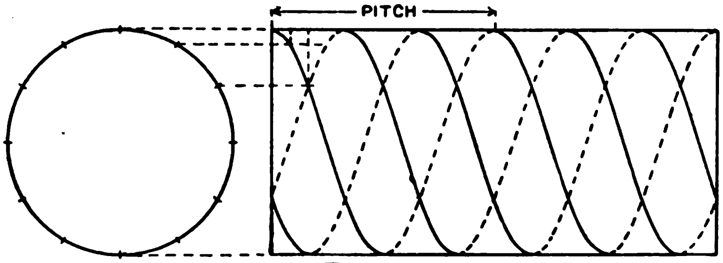



Fig. 29.

One complete turn of a screw causes it to travel through its nut a distance equal to its pitch.

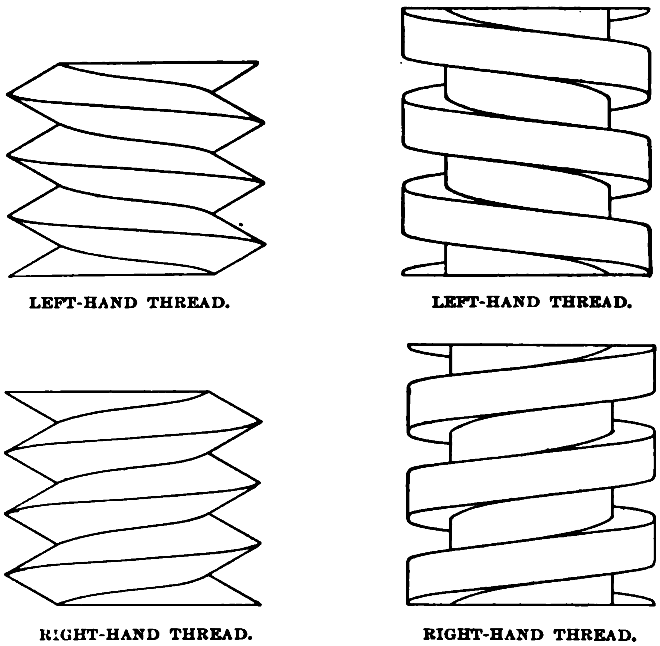



Fig. 30.

There are certain principles which apply and certain problems which arise, in connection with all forms of screws, and we shall now consider some of the most important of these.

Let Fig. 31 represent a jack screw. The pitch of the screw is P inches; the length of the bar from the axis of the screw to the point R, where the force is applied, is A inches. A force of F pounds is exerted at R, raising the weight W.

The following equation holds true,

$$\frac{F}{W} = \frac{\text{Distance W moves}}{\text{Distance F moves}} \qquad (7)$$

Suppose the screw to be turned once; then F will move through a distance approximately equal to the circumference of a circle whose radius is A; that is, F moves a distance $2\pi A$. In turning the screw once, W is raised a distance P. Then, substituting, in equation (7), these quantities for the distances which F and W respectively move, we get

$$(8)\ \frac{F}{W} = \frac{P}{2\pi A} \quad \text{or}$$

$$2\pi A F = W \times P$$

$$W \times P = 2\pi A \times F$$

From this equation, if any three of the quantities F, W, P or A are known, the fourth may be found. P and A must both be expressed in feet or both in inches.

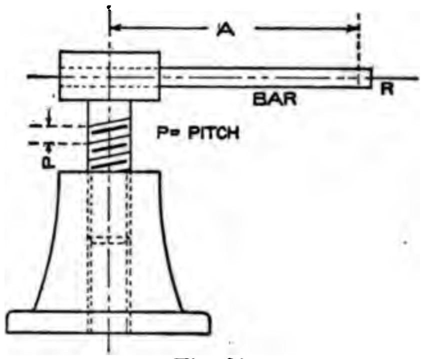



Fig. 31.

For example, let P = ¼ inch, A = 5 feet, F = 100 pounds. Substituting in the formule we get

$$\frac{100}{W} = \frac{.25}{2 \times 3.1416 \times 60}$$

$$.25\ W = 37699.2$$

$$W = 150{,}797 \text{ pounds (nearly).}$$

## EXAMPLES FOR PRACTICE.

1. Suppose a weight of 200,000 pounds is to be raised by a jack screw. The pitch is .20 inch, and the force applied is 125 pounds. What must be the length of the bar?

Ans. 51 inches (nearly).

2. What should be the pitch of the screw of example 1 if the bar is made 6 feet long? Ans. .28+ inches.

3. A jack screw has the following dimensions: Length of arm, $5\frac{1}{2}$ feet; pitch, .125 inch. If 200,000 pounds are to be raised what force must be applied at the end of the bar?

Ans. 60 pounds.

**Combination of Screws.** Fig. 32 illustrates a method by which the space moved through by the nut C may be made very small in comparison with the space moved through by a point on the circumference of the hand wheel, without using a very fine pitch on the screw. Great pressure can thus be produced at C by a small force on the wheel, without danger of stripping the thread, which might occur if the screw had a fine pitch. The upper part of the screw E has a coarse thread which acts in the nut B, this nut being rigid with the frame D. The lower part of the screw has a pitch different from the upper part and acts in the nut C. C is free to slide up or down in the frame, but is prevented from turning by the lips L.

Let $P =$ the pitch of the upper part of the screw and $p =$ the pitch of the lower part, both threads being right-hand, and P being greater than $p$. If the screw were attached to C by a collar instead of being threaded into it, one turn of the screw right-handed in nut B would cause the screw to advance a distance P, carrying C forward the same distance. But since by the same turn the screw has drawn nut C on to itself a distance $p$, the actual distance, K, which C has advanced is

$$K = P - p \tag{9}$$

If $p$ were greater than P, K would have a minus value; that is, C would actually move up for a right-handed turn of the screw. If one of the screws is left-handed and the other right-handed, the equation would become

$$K = P + p. \tag{10}$$

Let $P = \frac{1}{4}$ inch and $p = \frac{3}{16}$ inch, and let both screws be right-handed. If the radius A of the hand wheel is 12 inches, how much pressure can be exerted at C by a force of 50 pounds, applied to the circumference of the wheel?

The same principle holds here as in the case of a simple screw; that is, the forces exerted are inversely as the distances moved through, or,

$$\frac{\text{Force at wheel}}{\text{Force at C}} = \frac{\text{Travel of C}}{\text{Travel of point on circum. of wheel}} \quad (11)$$

so that we must first find the distance C moves for one turn of the wheel. Substituting the values of P and $p$ in formula (9), we get

$K = \frac{1}{4} - \frac{3}{16} = \frac{1}{16}$ = distance C moves for one turn of the screw.

The distance which a point on circumference of wheel moves

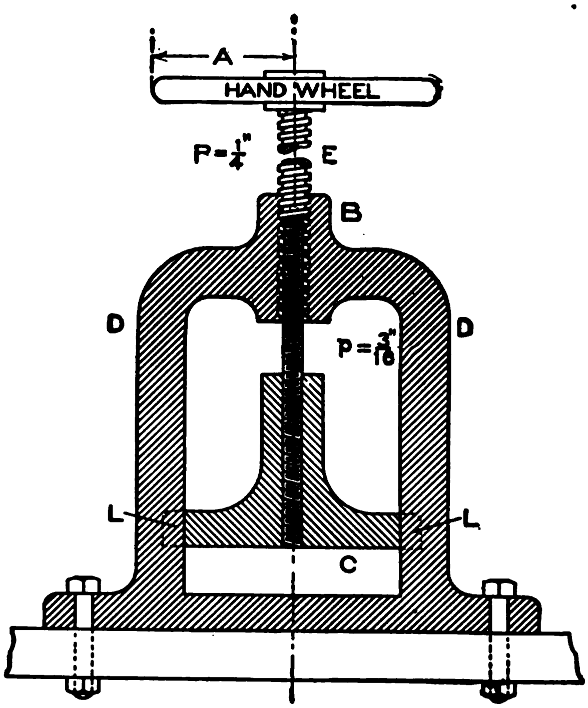



Fig. 32.

$= 2\,\pi\,A = 2 \times 3.1416 \times 12 = 75.4$ inches. Substituting these values in formula (11) we get

$$\frac{50}{\text{Force at C}} = \frac{\frac{1}{16}}{75.4}$$

Solving, we get, force at C = 60,320 pounds.

### EXAMPLE FOR PRACTICE.

1. Suppose the press shown in Fig. 32 has the following dimensions: $P = \frac{1}{5}$ inch, $p = \frac{1}{6}$ inch, and the force at C is to be 78,000 pounds. What force must be applied to the circumference of the wheel if it is 14 inches in diameter?

Ans. 60 pounds (nearly).

**Worm and Wheel.** The mechanism known as worm and wheel consists of a wheel, as A, Fig. 33, having teeth on its circumference, and a screw or worm W, meshing with the teeth on the wheel. The axis on which the wheel is fixed is usually at right angles to the axis of the worm. If the worm is turned, the action between it and the teeth on the wheel is similar to the action between a screw and the thread in a nut, so that the wheel will turn also. If the worm is single-threaded, one turn of the worm will cause the wheel to advance one tooth, so that in order for the wheel to make one complete revolution, as many turns of the worm will be required as there are teeth in the wheel. If the worm is double-threaded, half as many turns will be required as there are teeth in the wheel; if the worm is triple-threaded, one-third as many turns will be required as there are teeth in the wheel.

Suppose the worm be single-threaded and turned by a crank whose length is R; let the worm wheel have $n$ teeth and have on its shaft a cylinder of radius K, with a cord wound around it supporting the weight L. If a force of F pounds is applied to the crank, the same principle holds true as in the other mechanisms which we have studied, namely,

$$\frac{F}{L} = \frac{\text{Distance L moves}}{\text{Distance F moves}} \qquad (12)$$

If the worm makes one revolution, F will move through a distance $2\pi R$. The wheel makes $\frac{1}{n}$ revolutions, and consequently the cylinder to which L is attached will make $\frac{1}{n}$ revolutions. If the cylinder made a whole revolution it would raise L a distance equal to its circumference $= 2\pi K$, therefore, when it makes one revolution it will raise L a distance $\frac{2\pi K}{n}$ Substituting this value for the distance L moves, in formula (12), and substituting for distance F moves, the quantity $2\pi R$, we get

$$\frac{F}{L}=\frac{\frac{2\pi K}{n}}{2\pi R}=\frac{2\pi K}{2\pi nR}$$

Therefore,
$$\frac{F}{L}=\frac{K}{nR} \qquad (13)$$

If the worm is double-threaded, L will be raised twice as far for one turn of the worm, so that the above formula would become for a double-threaded worm and wheel,

$$\frac{F}{L}=\frac{2K}{nR} \qquad (14)$$

and for a triple-threaded worm and wheel,

$$\frac{F}{L}=\frac{3K}{nR} \qquad (15)$$

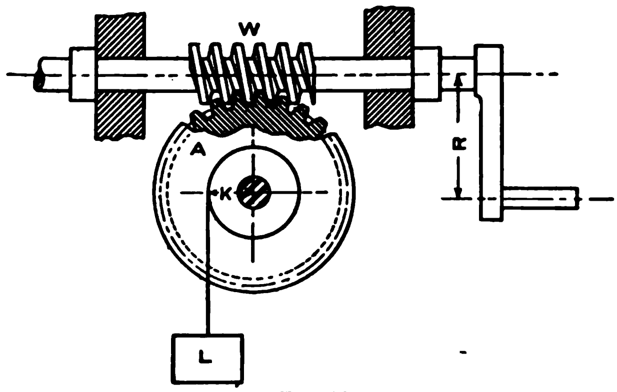



Fig. 33.

For example, a single-threaded worm makes 180 revolutions per minute and the worm wheel has 30 teeth, how many feet per minute will a weight be raised if the cylinder on the shaft of the worm wheel is 12 inches in diameter?

For each revolution of the worm wheel the worm must make 30 revolutions, hence the worm wheel makes 6 revolutions per minute. The circumference of the cylinder is $2\pi R$ or $2 \times 3.1416 \times 6 = 37.699$ inches and $6 \times 37.699 = 226.197$ inches $= 18.85$ feet.

## EXAMPLES FOR PRACTICE.

1. A crank of 18 inches radius is attached to a worm of a single thread. The worm wheel has 48 teeth and is attached to a drum 14 inches in diameter. What weight can be raised if 80 pounds is applied to the crank?

Ans. 9874 pounds.

2. If the crank in above device is given 216 revolutions per minute how fast will the weight rise?

Ans. $16\frac{1}{2}$ feet (nearly).

3. How fast would it rise if the worm has a double thread?

Answer 33 feet.

## CAMS.

A cam is a plate or cylinder having a curved outline, or a curved groove in it, which, by its rotation about a fixed axis, imparts a backward and forward motion to a piece in contact with it. The motion imparted to the follower may be at right angles to or parallel with the axis of the cam, or at some other angle.

The motions which cams are designed to give to their followers commonly belonged to one of the following kinds: uniform motion, harmonic motion, or "gravity" motion. The cam may give one kind of motion all the time or it may give different kinds of motion at different stages in its revolution.

Before studying the cams themselves, we will consider the three kinds of motions mentioned.

**Uniform Motion.** If a body moves through equal spaces in equal intervals of time, it is said to have uniform motion, that is, its velocity is constant.

**Harmonic Motion.** If a point as C, Fig. 34, travels around the circumference of a circle with uniform velocity, and another point, as E, travels across the diameter at the same time at such a velocity that it is always at the point where a perpendicular let fall from C would meet the diameter, the point E would be said to have harmonic motion. Its velocity will increase from the starting point A until it reaches the center O, and from O to D its velocity gradually decereases to zero at D.

**Gravity Motion,** or uniformly accelerated and retarded motion, is also a motion where the velocity gradually increases until it reaches a maximum at the middle of the path and from there gradually decreases to the end. The rate of increase and decrease, however, is different from that in harmonic motion, the velocity being increased in gravity motion, by equal amounts in equal intervals of time, the spaces traveled over in successive intervals of time being in the ratio of 1, 3, 5, 7, etc., to the middle of the path, and decreasing in the same ratio to the end.

The kind of motion which the follower is desired to have must be taken into consideration when designing a cam.

**Plate Cams.** Fig. 35 shows a plate cam designed to raise and lower the follower P with uniform motion. The point of P is raised from A to *e* while the cam turns right-handed through two-thirds of a revolution, and is lowered again to its original position during the remaining one-third of a revolution of the cam. In this cam the line of motion to the point of P passes through the point O, which is the center of the shaft on which the cam is fixed.

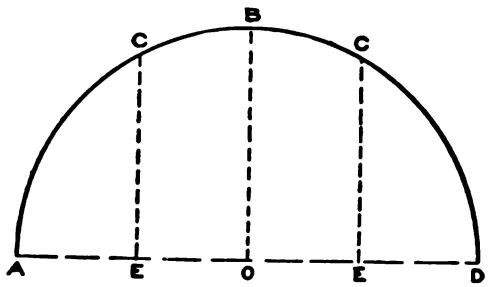



Fig. 34.

To design such a cam, draw a circle with O as a center and passing through A. Since the raising of P is to take place during two-thirds of a revolution, right-handed, find a point E on the circumference of the circle, such that the arc AHE shall be $\frac{2}{3}$ of the whole circumference, thus leaving arc ACE equal to $\frac{1}{3}$ of the circumference. Divide the arc AHE into any number of equal parts and draw the radial lines OF, OG, etc. Divide A*e* into the same number of equal parts and from the points of division 1, 2, 3, etc., thus found, swing arcs around the center O, cutting OF, OG, etc., at points *f*, *g*, etc., respectively. A smooth curve drawn through A, *f*, *g*, etc., to *m*, will give the outline of that part of the cam which raises P. The outline of the rest of the cam is found in a similar manner, by dividing arc ACE into any number of equal parts and making a new division of A*e* into the same number of equal parts, (points *d*, *c*, *b*.)

Fig. 36 shows a cam which gives the same motion to the follower as was given by the cam shown in Fig. 35, but in this case the line of motion of P, instead of passing through O, passes a distance O*a* to one side of O. The only difference in the method of designing this cam from that previously described is that instead of drawing radial lines through points A, F, G, etc., we draw lines

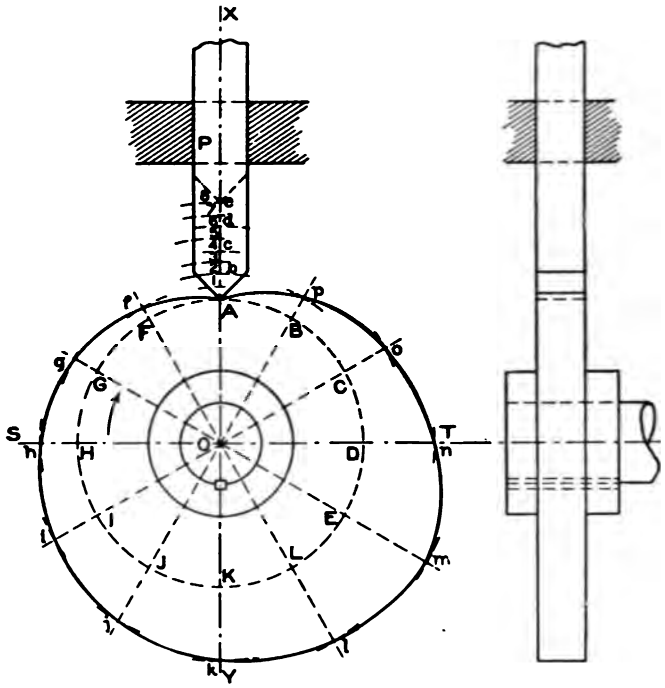



Fig. 35.

through these points tangent to a circle drawn with center O and radius O*a*.

If in Figs. 35 and 36 it had been required to raise P with harmonic motion instead of uniform motion, the only difference in construction would have been in making the divisions of A*e*. These divisions, instead of being equal, would be found as shown on a larger scale in Fig. 37. On the line A*e* as a diameter, draw a semicircle and divide this semicircle into as many equal parts as we divided the arc AHE in Figs. 35 and 36. From the points

BCD, etc. (Fig. 37), draw perpendiculars to line A$e$, cutting it at points 1, 2, 3, etc. The division A – 1, 1 – 2, etc., thus found, are the divisions of A$e$ which would be used in finding the cam outline, in place of the equal divisions which were used for uniform motion.

Fig. 38 shows how A$e$ would be divided if the motion were

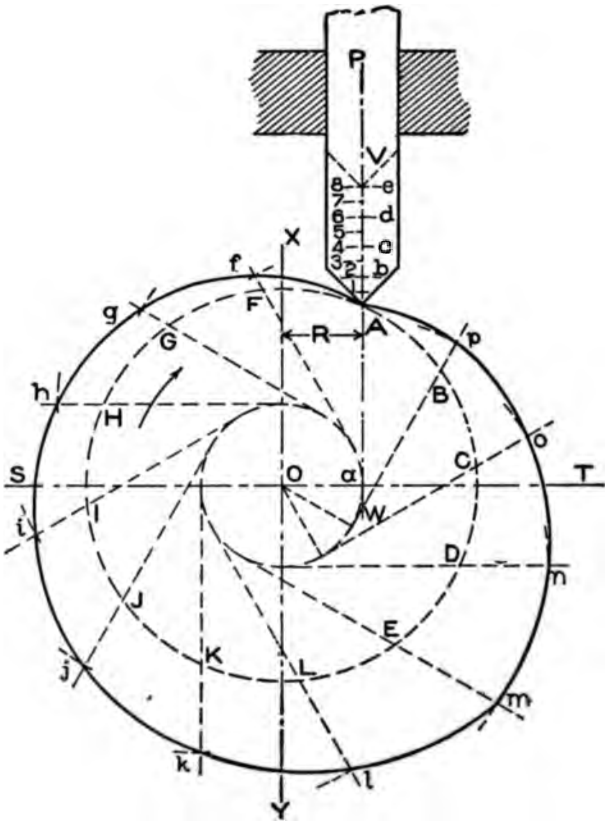



Fig. 38.

to be "Gravity." Since A$e$ is to be divided into as many equal parts as arc AHE, in this case it will be divided into eight parts. Now if the motion which the cam is to give to piece P is to be uniformly accelerated and retarded (that is, gravity motion), A$e$ must be divided in such a way that the distance from 1 to 2 is three times the distance from A to 1; the distance from 2 to 3 is five times the distanco from A to 1; 3 to 4 is seven times A to

1; 4 to 5 is seven times A to 1; 5 to 6 is five times A to 1; 6 to 7 is three times A to 1; and 7 to *e* is equal to A to 1. Therefore the whole line A*e* is 1+3+5+7+7+5+3+1 or 32 times the distance from A to 1, or in other words, A–1 is $\frac{1}{32}$ of the whole line A*e*, and 1–2 is $\frac{3}{32}$ of A*e*, and so on. To divide A*e* so that the divisions may bear this relation to each other, draw the line AR at any convenient angle, and choosing any convenient distance as a unit, mark it off on AR thirty-two times, beginning at A. From I, the last of these dividing points, draw a line to *e*; next find the points B, C, D, etc., as follows: B is the first division from A, C the third from B, etc., thus getting the divisions of A1 in the ratio 1, 3, 5, 7, 7, 5, 3, 1. From the points B, C, D,

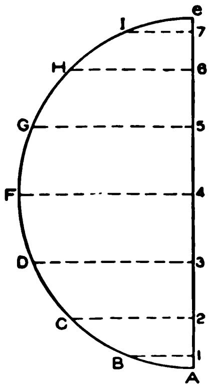



Fig. 37.

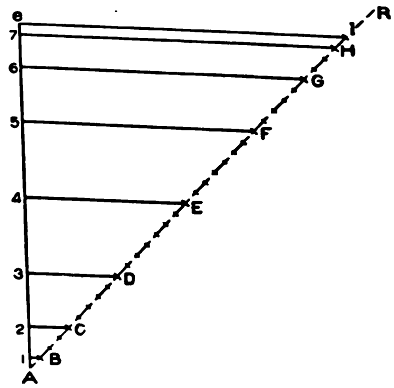



Fig. 38.

etc., draw lines parallel to I*e*, meeting A*e* at 1, 2, 3, etc., which will be the required points of division.

The cams which we have been considering all act on the comparatively sharp end of the piece P, and consequently much friction and rapid wearing will result if much power is transmitted. Fig. 39 shows a cam designed to act on a roller. The outline is first found for a cam to act on a piece like those in the preceding cases, with its point at the center of the roller. This curve is shown dotted in the figure. Next, with a radius equal to the radius of the roller, and with centers at any number of points around the dotted curve, draw arcs as shown. A smooth curve drawn *tangent* to these arcs will be the outline of the cam which is to act on the roller.

**Cylindrical Cams.** A plate cam, such as we have been considering, can be designed to give almost any kind of motion in a plane at right angles to the axis of the shaft on which the cam is located, but can not give motion parallel to the axis of the shaft. If, however, we place on the shaft a cylinder with a groove cut in it, the shape of the groove may be made such as to give to a piece inserted in it almost any motion along the shaft; or, if the depth of the groove be varied, the follower may be given a motion which shall be made up of two components, one along the shaft and one at right angles to the shaft.

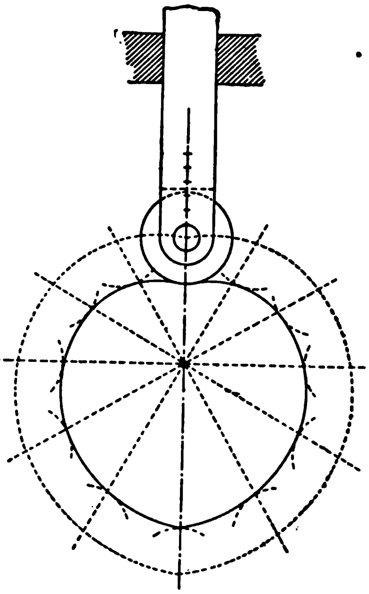


Fig. 39.

Fig. 40 shows two views of a cam designed to give a backward and forward motion in a line parallel to the axis of the shaft.

Familiar illustrations of the use of plate cams are found in the bobbin-winding mechanism on some sewing machines; on

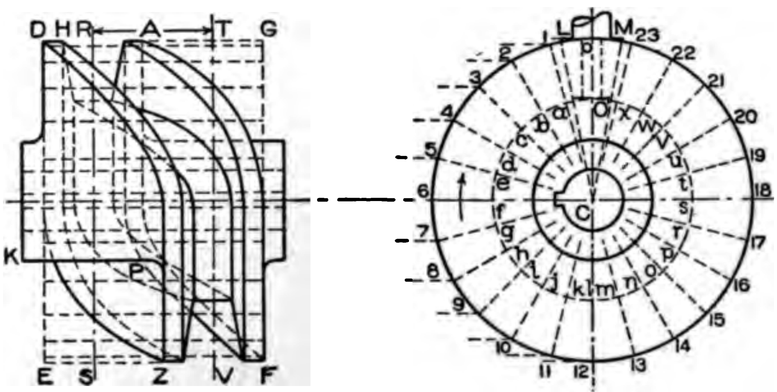



Fig. 40.

many kinds of looms, and in the valve gear on the Brown and other steam engines. Cylindrical cams are used in many places in textile work and in machine tools. One very common use is in stretchers on many forms of cloth-finishing machinery.

### LEVERS.

A lever is a rigid piece supported at some point called the fulcrum, and so arranged that when force is applied at a certain point in the piece, work is done at a certain other point by reason

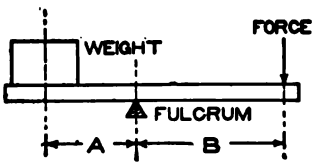



Fig. 41.

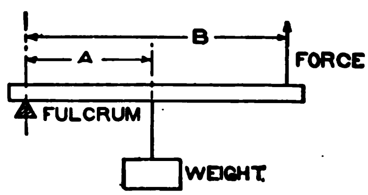



Fig. 42.

of the pivoting action around the fulcrum. Figs. 41, 42 and 43 illustrate the three common kinds of levers, the difference consisting in the relative positions of the force applied and the weight lifted, with respect to the fulcrum. In any of the three cases, if we let F = force applied, W = weight lifted, A = distance from fulcrum to weight, and B = distance from fulcrum to F, we have the following equation:

$$F \times B = A \times W \text{ or}$$

$$(16) \qquad \frac{F}{W} = \frac{A}{B}$$

from which, if any three of the quantities are known, the fourth may be found.

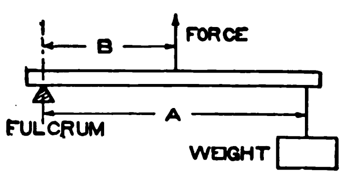



Fig. 43.

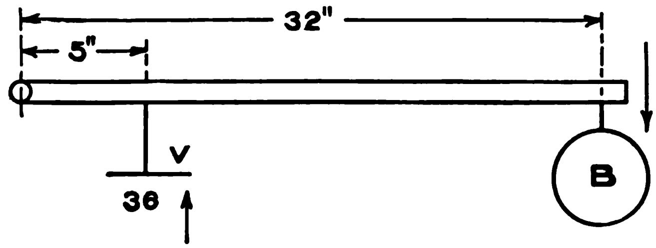
Distance A is called the *weight arm*, and distance B is called the *power arm*. The product of A times the weight is called the moment of the weight, and the product of B times the force is called the moment of the force. Another way of stating the principle expressed in equation (16) is:

Moment of force = moment of weight.

Example: Suppose a weight of 40 pounds is hung on the end of a lever. If the distance from the fulcrum to the weight is 14 inches, what power must be applied to raise the weight, the distance from the fulcrum to the power being 18 inches?

$$F \times B = A \times W$$
$$F \times 18 = 14 \times 40$$
$$F = \frac{14 \times 40}{18}$$
$$= 31.11 \text{ pounds.}$$

Another example: Let the accompanying diagram represent a safety valve. We will neglect the weight of the lever and valve. Suppose the valve V has an area of 3 square inches and the steam pressure per square inch is 36 pounds. The valve is 5 inches from the fulcrum and the weightis 32 inches from the fulcrum. What should be the weight of the ball B?




First, let us find the moment of power. The total upward pressure is $3 \times 36 = 108$, because the total steam pressure equals the pressure per square inch multiplied by the area.

The moment of power is $108 \times 5 = 540$.

The moment of weight is $32 \times B$.

$$\text{Then } 32 \times B = 540$$
$$B = \frac{540}{32}$$
$$= 17 \text{ pounds (nearly).}$$

Had we considered the weight of the valve and lever, we would have added their moments to that of the weight, because these weights increase the weight but not the power.

If in addition to the data given above, the lever weighs 10 pounds and its center of gravity is at its center, that is, 16 inches from the fulcrum. Then

$$\text{Moment of lever} = 10 \times 16 = 160.$$

The valve and valve spindle weigh 8 pounds and are 5 inches from the fulcrum, hence

$$\text{Moment of valve} = 8 \times 5 = 40.$$

$$\text{Total moment of weight} = 32 \times B + 200.$$

The moment of power is, from the previous example, 540, and we have the equation

$$32 \times B + 200 = 540$$

$$32\,B = 540 - 200.$$

$$32\,B = 340$$

$$B = \frac{340}{32} = 10.62 + \text{pounds.}$$

Thus we see that by considering the weight of the valve and spindle and that of the lever, the ball can be reduced in weight from 17 to 10⅝ pounds.

If the lever is curved as in Fig. 44, the weight arm A becomes the length of the perpendicular from the fulcrum to the line of action of the weight, and the power arm B the length of the perpendicular from the fulcrum to the line of action of the force.

## LINK WORK.

**Four-Bar Linkage.** If we have the four rods AB, BC, CD and DA, Fig. 45, each connected to two of the others by pin and eye joints, each rod becomes what is called a link, and the whole forms a four-bar linkage. If the link AB is fixed in a position (as regards the frame of the machine) the pins at A and B become fixed centers, the links AD and BC become what are called cranks, and the link CD becomes a connecting link or connecting rod. If AD is caused to turn with a uniform angular speed about the pin of A, that is, turning through equal angles in equal periods of time, BC will be compelled to turn with some sort of motion about pin B. Whether BC shall have uniform angular motion and whether it shall make complete revolutions for complete revolutions of AD, will depend upon the relative lengths of the four links.

The center line drawn through the fixed link AB is called the line of centers, and the center line drawn through the connecting rod CD is called the line of connection. Whatever the relative lengths of the various links, the following law holds true for any position of the linkage.

$$\frac{\text{Angular velocity of crank A D}}{\text{Angular velocity of crank B C}} = \frac{\text{B H}}{\text{A K}} = \frac{\text{B E}}{\text{A E}} \qquad (17)$$

That is, if at any given instant the connecting rod be imagined removed and the cranks continue turning at the same speed at which they were moving when the connecting rod was removed, the number of turns of the cranks in a given period of time would be to each other inversely as the lengths of the perpendiculars drawn from the respective fixed centers to the line of connection, and also inversely as the distances from the fixed centers to the point where the line of connection meets the line of centers. A mathematical proof can be given for this law, but it will not be considered here.

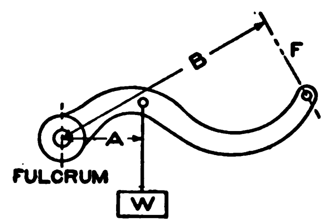


Fig. 44.

If the fixed link AB is made equal in length to the connecting rod DC, and the two cranks are equal (see Fig. 46), the connecting rod will always be parallel to the fixed link, and the perpendiculars BH and AK will always be equal, so that from equation (17) it will be evident that the speeds of the cranks are always equal. An example of a linkage of this kind is found in the parallel rod connecting the drivers of a locomotive, as shown in Fig. 47. The axles of the drivers form the fixed centers A and B, the

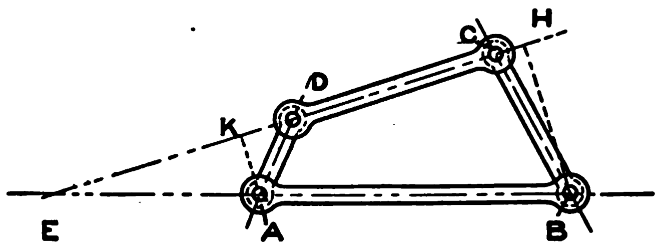


Fig. 45.

frame of the locomotive forms the fixed link AB, the drivers themselves form the cranks AD and BC, and the parallel rod forms the connecting link.

**Crank and Connecting Rod.** In the four-bar linkage shown in Fig. 45, the pin C is compelled by crank BC to move on the

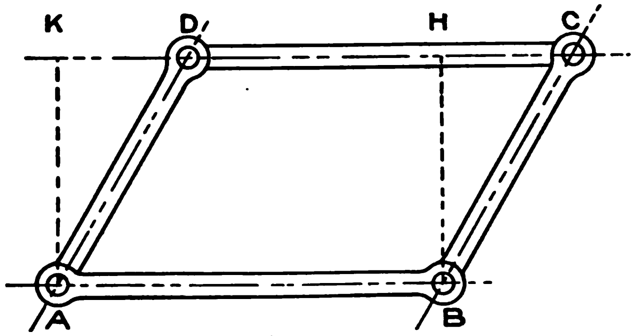



Fig. 46.

arc of a circle whose center is B and radius BC. If in place of BC the fixed link is formed as shown in Fig. 48, being provided with a slot whose radius is BC and center is B, the pin C on the end of the connecting rod will have exactly the same motion that it would if guided by the crank BC. Now, if the radius of the slot

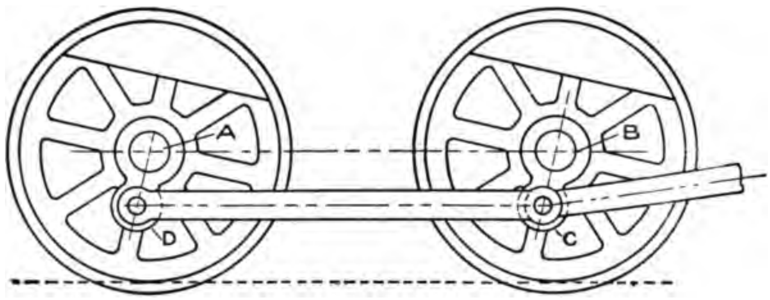
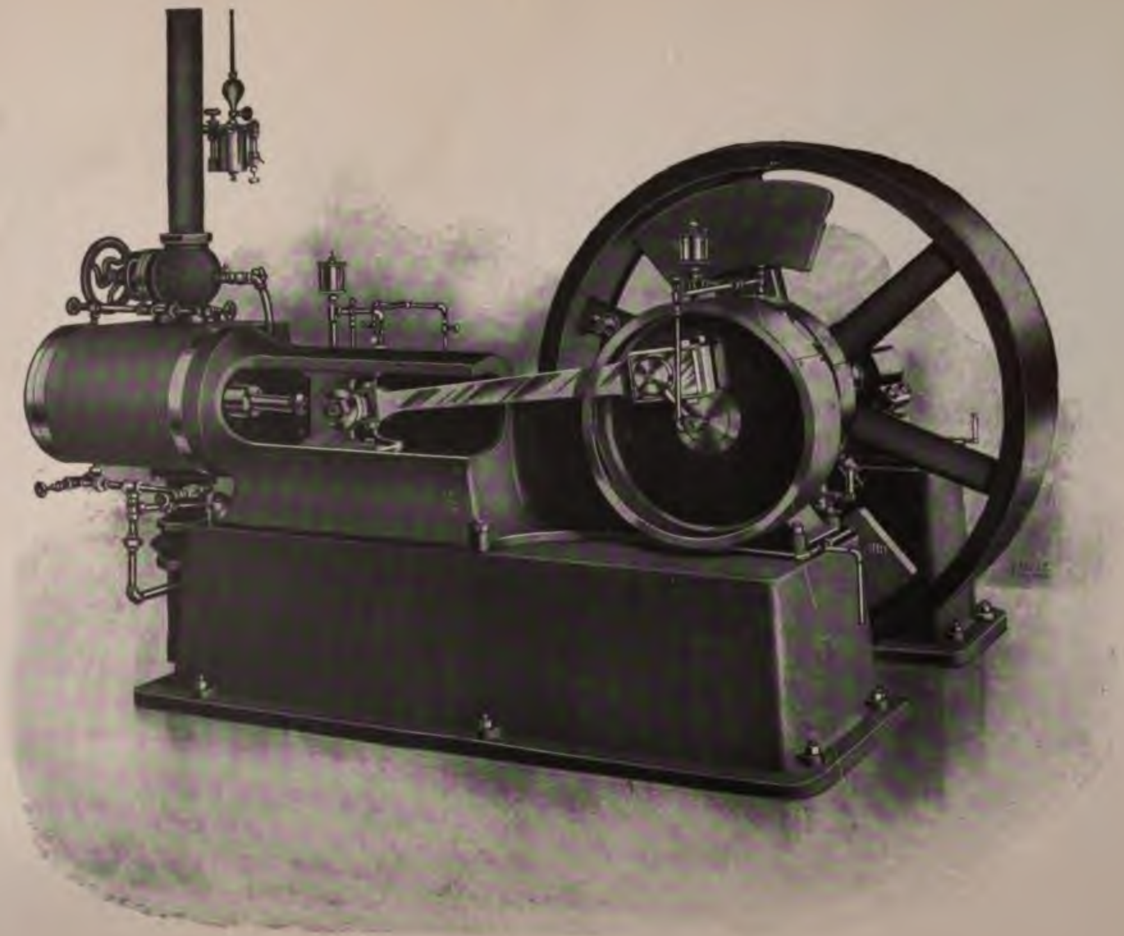



Fig. 47.

is gradually increased, the slot will become nearer and nearer to being straight, so that the linkage shown in Fig. 49, where the slot is straight, may be said to be the limiting case of the linkage shown in Fig. 48. This is the linkage which we have in the crank, connecting rod, crosshead and crosshead guides of a steam engine. The crank shaft corresponds to the pin A, the frame and guides



**TWENTIETH CENTURY ENGINE. BELTED TYPE.**
The Brownell Company.

take the place of the slotted link AC, DC is the connecting rod, and AD the crank.

As there are many problems which may arise in connection with this linkage, particularly as applied to the steam engine, we will consider the most important.

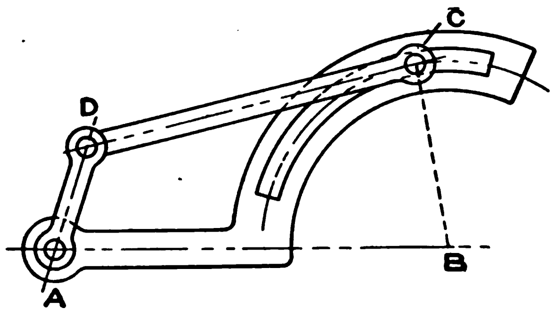



Fig. 48.

Fig. 50 shows the same linkage, the links being represented by their center lines only. AD is the crank, DC the connecting rod, C the crosshead and AC the center line through the crank shaft and the guides.

Suppose the crank has a length R and is making N revolutions per minute at a uniform speed, to find how fast the crosshead is moving at any given position of the crank.

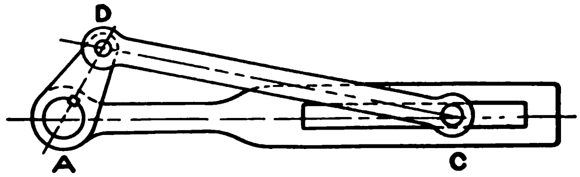



Fig. 49.

We will solve this problem partly graphically and partly by calculation. The first step is to find how fast the crank pin D is moving. For one turn of the crank, D travels through a distance equal to the circumference of a circle whose radius is R, that is, a distance of $2\pi R$. If the crank turns N times per minute the velocity of D must be $2\pi RN$. Knowing the value of R and N, for any particular case we can substite in this formula and find the actual velocity of D. Next draw the linkage at a convenient scale, in the position in which it is desired to find the velocity of C. Draw D*d* perpendicular to AD and make its length represent at a convenient scale (not necessarily the same scale as was used for the links) the calculated velocity of D. This represents the actual velocity and direction of motion of the end D of the connecting rod at the instant under consideration. Now resolve the velocity D*d* into its components, along and at right angles to DC, by prolonging the

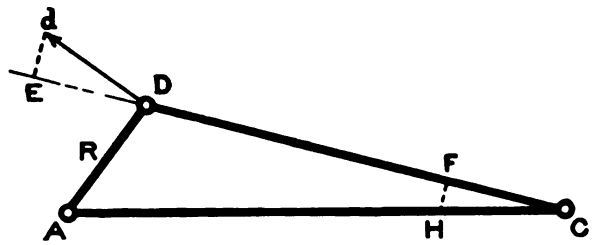


Fig. 50.

line DC and drawing *d*E perpendicular to it. The component DE is the only one which has any effect on the motion of the point C. We have already learned that the motion of the two ends of a rod must have their components along the rod equal, therefore lay off from C, CF = DE. The actual motion of C is along the line CA, and, as CF is one component of the motion, the other component

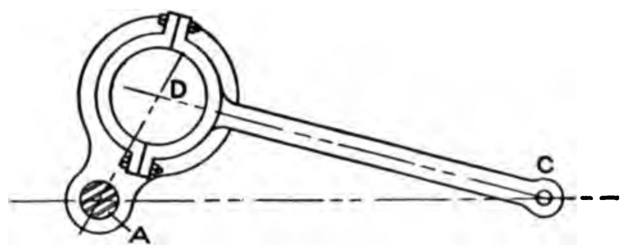


Fig. 51.

must be perpendicular to CF, therefore draw FH perpendicular to CF and meeting CA at H. Then CH is the velocity of point C at the same scale at which D*d* was drawn.

**Eccentric.** The eccentric and eccentric-rod linkage is in principle the same as the crank and connecting rod. To trace out the connection between the two, let us consider the crank and connecting rod shown in Fig. 51. Here the crank pin D is large and comes almost to the center of the shaft A. By increasing still further the diameter of the pin D, so that it will take in the shaft, as shown in Fig. 52, we obtain the eccentric.

Considering again the crank and connecting rod linkage: Suppose that in Fig. 53 a force F is applied at the crank pin D in a direction perpendicular to the center line AD; then the pressure which would be exerted by the slide C could be found by the same principle which we have used in previous cases, namely, the forces are inversely proportional to the velocities. Let F be the force at D, and P the pressure at C. Assume any velocity of the point D and represent this at some scale by the line D*d* perpendicular to AD. Then find the velocity CH of the point C along the line AC, in the same manner as in Fig. 50. The value of CH can be measured off at the same scale at which D*d* was drawn. Then

$$\frac{F}{P} = \frac{CH}{Dd} \qquad (18)$$

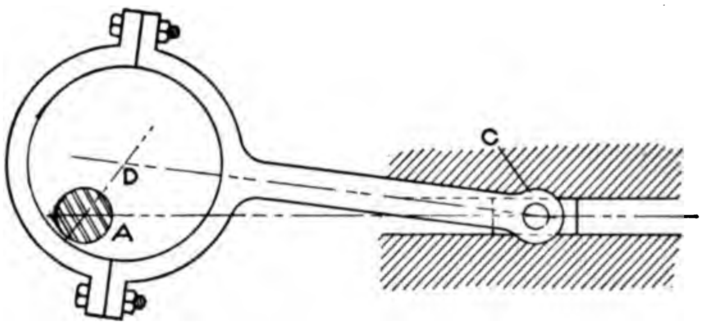



Fig. 52.

from which, if one of the quantities F or P is known, the other may be found.

If the value of CH is found for various positions of AD, keeping D*d* constant, it will be seen that the nearer AD comes to coinciding with AC, the smaller CH becomes, and from equation (18) it will appear that the smaller CH is, the greater P becomes with relation to F. The above discussion will hold true if the force acts in the direction D*d* or in the opposite direction.

The linkage used in this way to effect pressure at *c* by a force on D is known as the *toggle joint*, and is used with more or less modification in several kinds of machinery, such as punching machines, brakes on the drivers of a locomotive, etc. The force need not be applied at D, but may be applied at some other point on AD, or on some piece rigidly connected to AD but making an angle with it. This is shown in Fig. 54. Here the force is applied at E, and we can find the force at C by the same principle as before: The force at C is to force at E inversely as the veloci-

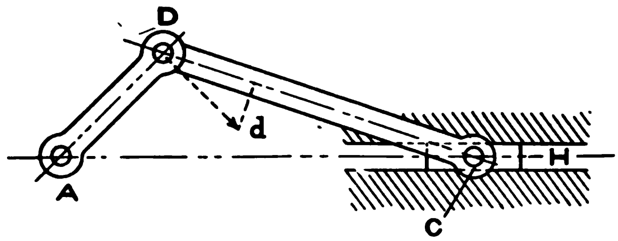



Fig. 53.

ties of C and E. The only difference is in finding the velocity of C. Assume a velocity for E, as E*e*. Then

$$\frac{\text{Velocity E}}{\text{Velocity D}} = \frac{\text{A E}}{\text{A D}} \qquad (19)$$

from which the velocity of D may be found; the rest of the solution would be the same as for Fig. 53.

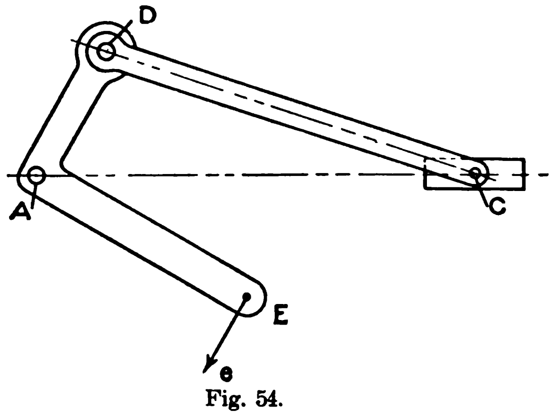



Fig. 54.

These problems may be solved by another and perhaps somewhat shorter method, but, as this would involve the resolution of forces, which have not yet been taken up in detail, we will confine ourselves to the above method.

## QUICK RETURN MOTIONS.

In various kinds of machinery, particularly machine tools, it is desired to move a piece backward and forward; the forward motion being slow and the return motion more rapid. Take for example the shaper; as the tool when moving forward is cutting metal, it should go slowly and steadily, but after the cut is made it is desirable to get the tool back ready for its next stroke as quickly as possible. Many different devices are used to accomplish this result.

If in Fig. 45 we replace the connecting rod DC by a slot in the link BC, we get the linkage shown in Fig. 55. A and B are the fixed centers, AD is the driving crank (which usually turns

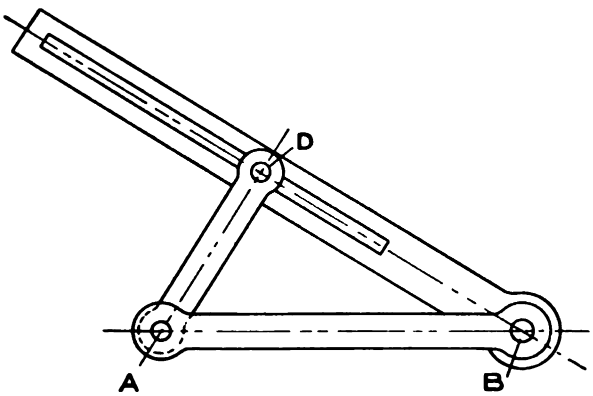



Fig. 55.

with uniform speed), BD is the slotted crank and to some part of BD a link or some other piece is connected by means of which the tool is driven. Two distinct mechanisms are formed, depending upon the relative lengths of the links. If the proportions are such that a circle drawn around the center A, with radius AD, falls outside the center B, as shown in Fig. 56, we have what is known as a Whitworth quick return motion. Here the slotted crank makes one complete revolution for each complete revolution of AD, but its speed is not uniform. In this figure, a connecting rod PT is represented as attached to a point P on the slotted link. The other end of this connecting rod moves the tool holder T along the straight line BT. When the linkage is in the position shown, T is in its extreme right-hand position, and it will be in its extreme left-hand position when BP occupies the position $BP_1$. In turning BP through this angle (180°), AD has turned through the angle L. In returning BP to its right-hand position again, AD has to turn through the angle M only. Now, since AD turns with uniform speed and since angle M is less than angle L, T makes its stroke from left to right in less time than was required to move from right to left. The time of advance and time of return are in the ratio of angles L and M. If the length of the crank AD and the ratio of time of advance to return are known the distance AB may be found as follows:

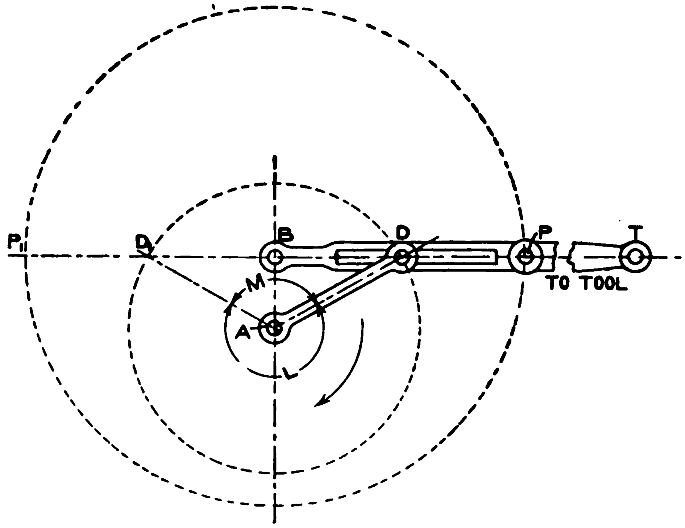



Fig. 56.

With A as a center and AD as a radius, draw a circle and divide the circumference by the points D and $D_1$ so that angle L may bear the same ratio to angle M that the time of advance bears to the time of return. Join D and $D_1$ and from A draw a line perpendicular to $DD_1$, meeting it at B, which will be the required center for the driven crank.

The distance BP governs the length of the stroke of the tool, so that by varying the position of P the length of the stroke may be varied.

If the proportions of the linkage are such that a circle drawn with A as a center and a radius AD comes inside the point B, that is, if AD is less than AB, we have what is known as a swinging block linkage. Fig. 57 shows this form of quick return motion. The piece which drives the tool is attached to the slotted link at P, which may be anywhere along the link. The linkage is shown at the extreme right of its stroke, the point D being at the point where the center line of the slot is tangent to the circle drawn with center A and radius AD, (that is, the length of the driving crank). $AD_1$ is the corresponding position of the crank

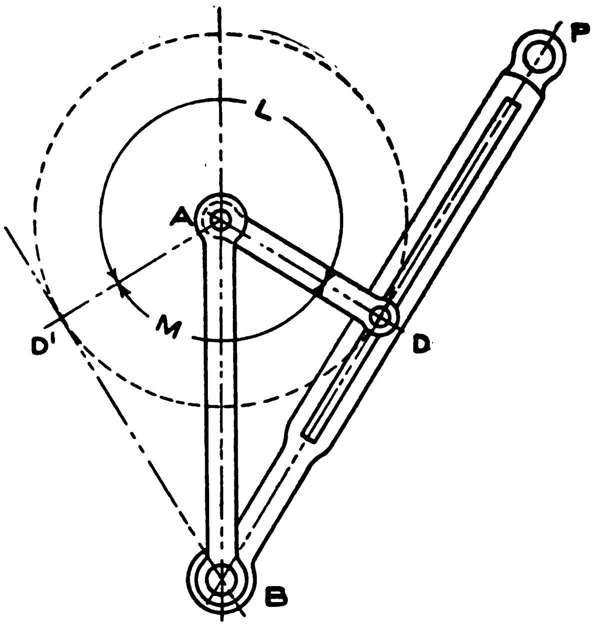



Fig. 57.

at the other extreme of the stroke. The time of advance is to the time of return as angle L is to angle M, as in the case of the Whitworth quick return. If the ratio of advance to return and the length of AD are known, the position of B may be found by drawing the circle with center A and radius AD, and on this circle finding points D and $D_1$ such that the angles L and M shall have the required ratio. Then draw DB and $D_1B$ tangent to the circle at D and $D_1$ respectively, meeting each other at B, which is the required center for the driven crank.

## GEARING.

If shaft B, Fig. 58, has fastened to it a disc with smooth circumference, the disc being in contact at the point P with another disc on shaft A, the rotation of one shaft will cause the other to rotate, provided there is sufficient friction between the two surfaces to prevent slipping. According to the principles which we have already learned, the following equation will hold true:

$$\frac{\text{Revolutions per minute of A}}{\text{Revolutions per minute of B}} = \frac{\text{B P}}{\text{A P}}$$

In practice, the friction would not be sufficient to be relied upon, so that discs having teeth upon their circumference are used, instead of the plain discs. The discs or wheels thus formed are called gears. The teeth may have any one of several forms, and the gears may connect shafts which are parallel, intersecting at some angle, or neither parallel nor intersecting. Two gears such as shown in Fig. 59, where the shafts are parallel and the teeth on the circumference are parallel to the axis of the gear, are called **spur gears.**

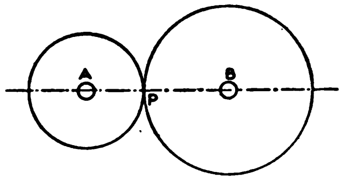
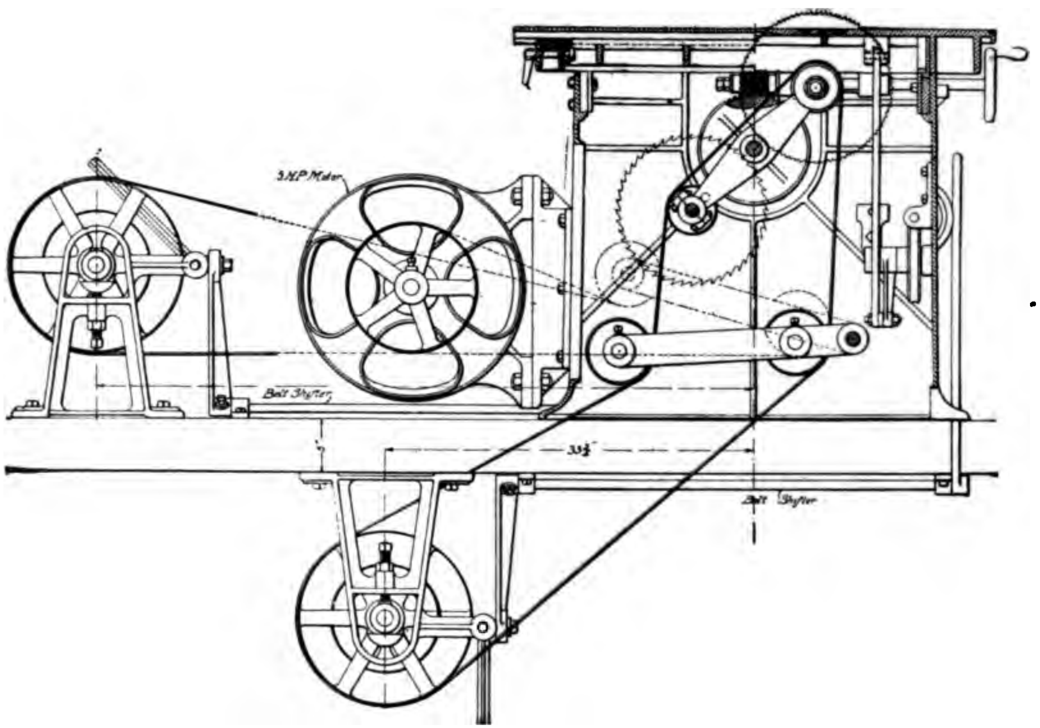


Fig. 58.

The two dot and dash circles drawn about the centers A and B and in contact at P correspond to the two discs of Fig. 58, and the gears may be said to be derived from these circles, which are called the **pitch circles.** The diameters of these circles are called the **pitch diameters** of the gears. The point P, where the two pitch circles touch each other, is called the *pitch point.* Circles drawn through the outer ends of the teeth are called the *addendum cirles.*, and circles drawn at the bottom of the teeth are called the *root circles.* These circles are indicated on the figure. That part of the tooth outlined between the pitch circle and the addendum circle; as PE, is called the **face** of the tooth, and that part between the pitch circle and the root circle, as PF, is called the **flank.** The radius of the addendum circle minus the radius of the pitch circle is called the addendum distance, or simply the *addendum.* The radius of the pitch circle minus the radius of the root circle is called the *root distance* or the *root.* The root is commonly




**REVOLVING MECHANISM, UNIVERSAL SAW BENCH.**
Oliver Machinery Company.

made a little greater than the addendum, so that when two gears have their pitch circles in contact, if their teeth are of equal length they will not touch bottom, but will have some clearance. The distance from the center of one tooth to the center of the next, measured on the pitch circle, as GH, is called the **circular pitch,** or **circumferential pitch,** and is equal to the circumference of the pitch circle divided by the number of teeth.

In order to run together, two gears must have the same circular pitch. The number of teeth on two gears of the same pitch are proportional to the circumferences, and, consequently, to the diameters of their pitch circles; and as the speeds of the two shafts

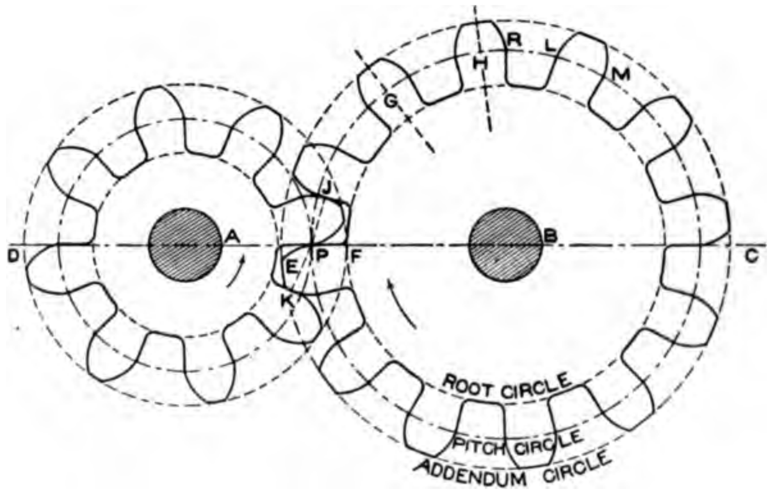



Fig. 59.

which are connected by a pair of gears are inversely proportional to the diameters of the pitch circles of the gears, the speeds must also be inversely proportional to the number of teeth.

On rough gears the width of the tooth LM is made a little less than the width of the space RL, to allow for irregularity of construction. The difference in the width of the two is called the *back lash.*

Although the circular pitch is a term which is frequently used in connection with gearing, there is another kind of pitch which is often used. This is the **diametral pitch,** and is equal to the diameter of the pitch circle divided by the number of teeth, or, in other words, the amount of pitch diameter allowed for each

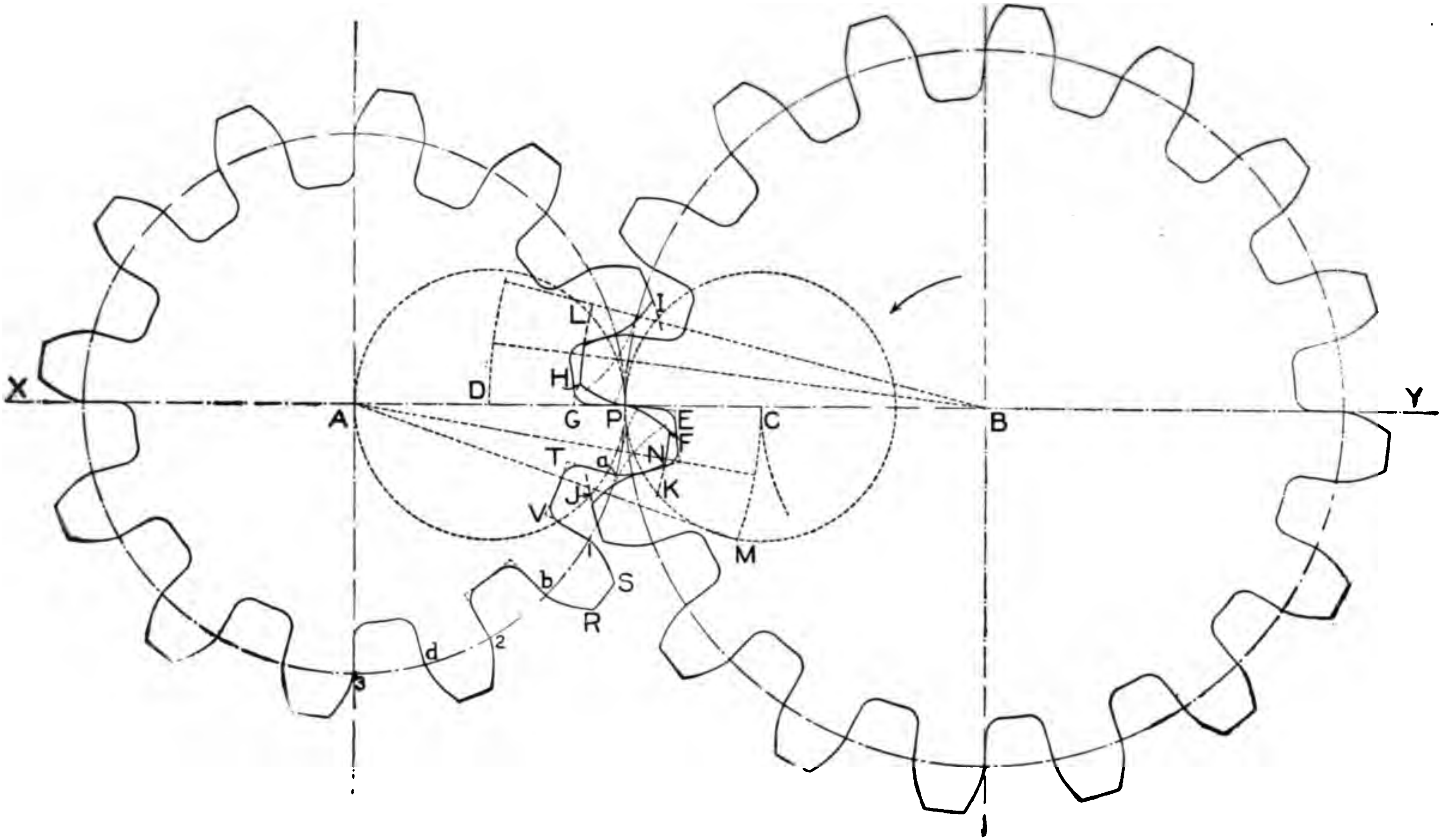



Fig. 60.

tooth. The diametral pitch bears the same relations to the circular pitch that the diameter of a circle bears to its circumference; that is, the diametral pitch is equal to the circular pitch divided by $\pi$. In speaking of the pitch of a gear, instead of using the diametral pitch, which is often a fraction, it is customary to use only the denominator of the fraction. For example, if the diametral pitch is $\frac{1}{2}$ inch, it would be spoken of as a 2-pitch gear. This would be the same as saying that for every inch of pitch diameter there are two teeth.

Problems similar to the following often arise in this connection:

1. Given two gears, 4 pitch, having 12 teeth and 16 teeth respectively, to find their pitch diameters and the distance apart that their centers should be located, to run properly.

Since they are 4 pitch, their diametral pitch is $\frac{1}{4}$ inch and their pitch diameters will be their numbers of teeth multiplied by $\frac{1}{4}$, so that one would be $12 \times \frac{1}{4} = 3$ inches in diameter, and the other $16 \times \frac{1}{4} = 4$ inches in diameter. The distance on centers will be the sum of their pitch radii $= \frac{3}{2} + \frac{4}{2} = 3\frac{1}{2}$ inches.

2. Given two gears, 8 pitch, having diameters 6 and 10 inches respectively, to find the number of teeth.

The expression "8 pitch," besides meaning that the diametral pitch is $\frac{1}{8}$ inch, means that there are 8 teeth for every inch of diameter, so that one gear will have

$$8 \times 6 = 48 \text{ teeth}$$

and the other $$8 \times 10 = 80 \text{ teeth.}$$

Referring again to Fig. 59: If gear A is driving the other gear in the direction indicated, there is a working point of contact between the teeth of the two gears at J and another at K, and as the gears turn and the teeth slide along each other, the point where a pair of teeth is in contact changes. If from the point of contact, as J, a line is drawn to the pitch P, the tooth curves should have such form that this line is normal to both curves at J; that is, PJ should be perpendicular to a line drawn tangent to both curves at J. This condition should hold, wherever the point of contact may be, in order that the gears may run smoothly.

There are two kinds of curves which are commonly used for the outlines of gear teeth, and which fulfill the above conditions.

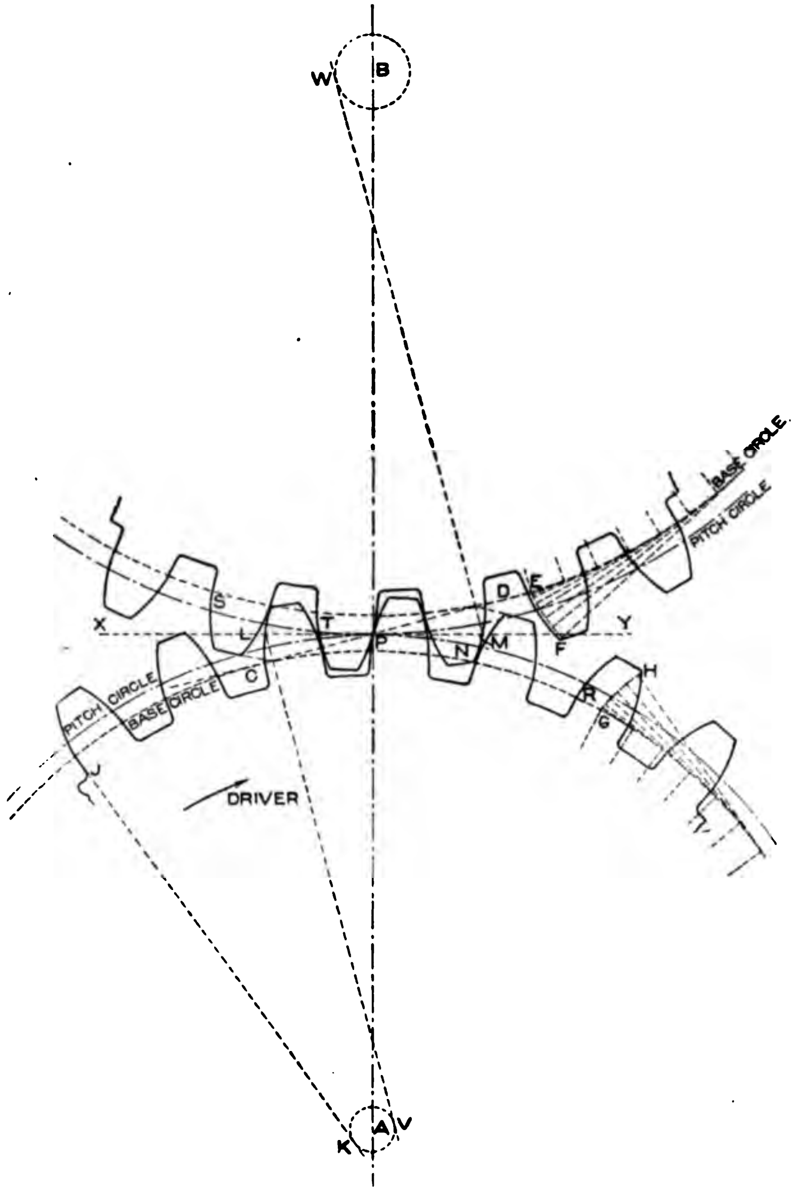

W
B
BASE CIRCLE
PITCH CIRCLE
S
D
E
X
L
T
Y
P
N
M
F
C
H
R
G
PITCH CIRCLE
BASE CIRCLE
DRIVER
J
K
A
V

Fig. 61.

These are the **involute** and the **epicycloidal** curves. Fig. 60 shows a pair of gears with epicycloidal teeth and Fig. 61 shows parts of two gears with involute teeth. The construction for getting the tooth outlines is shown in the figures, but as this properly comes under the subject of drawing, and is not essential to an understanding of gears in general, it will not be explained here.

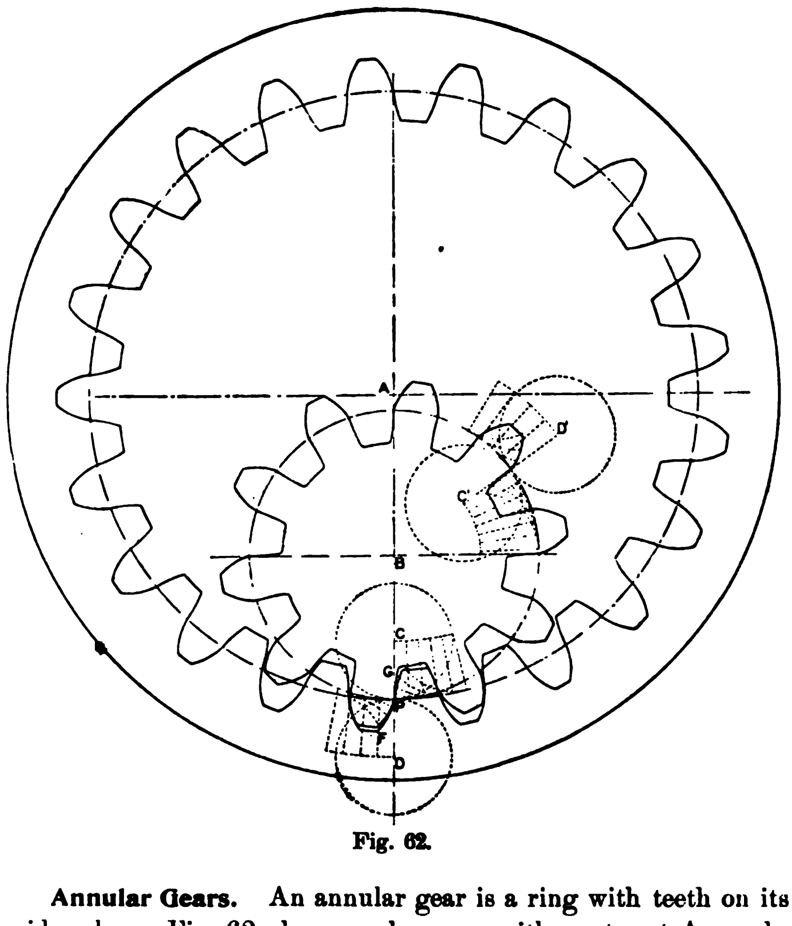



Fig. 62.

**Annular Gears.** An annular gear is a ring with teeth on its inside edge. Fig. 62 shows such a gear with center at A, meshing with a small spur gear called the pinion.

**Rack and Pinion.** A rack is a gear whose pitch line is a straight line instead of a circle. Fig. 63 shows an epicycloidal rack in gear with a pinion.

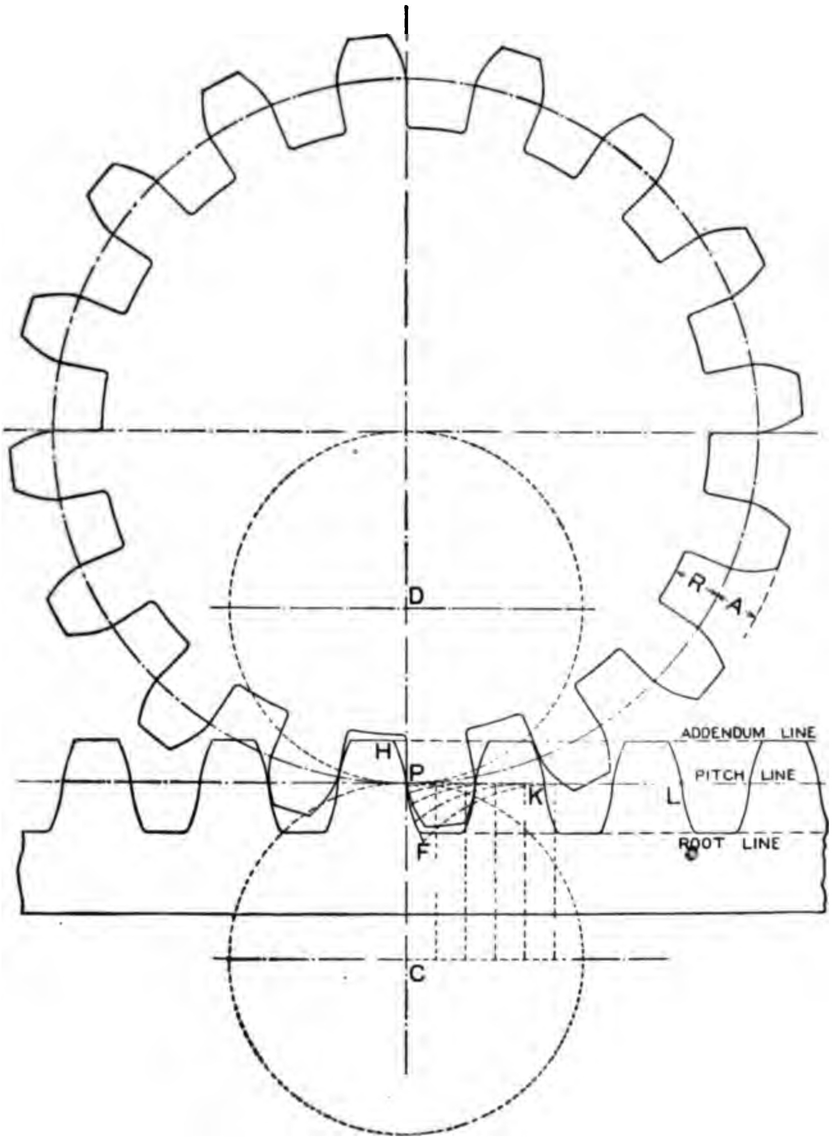
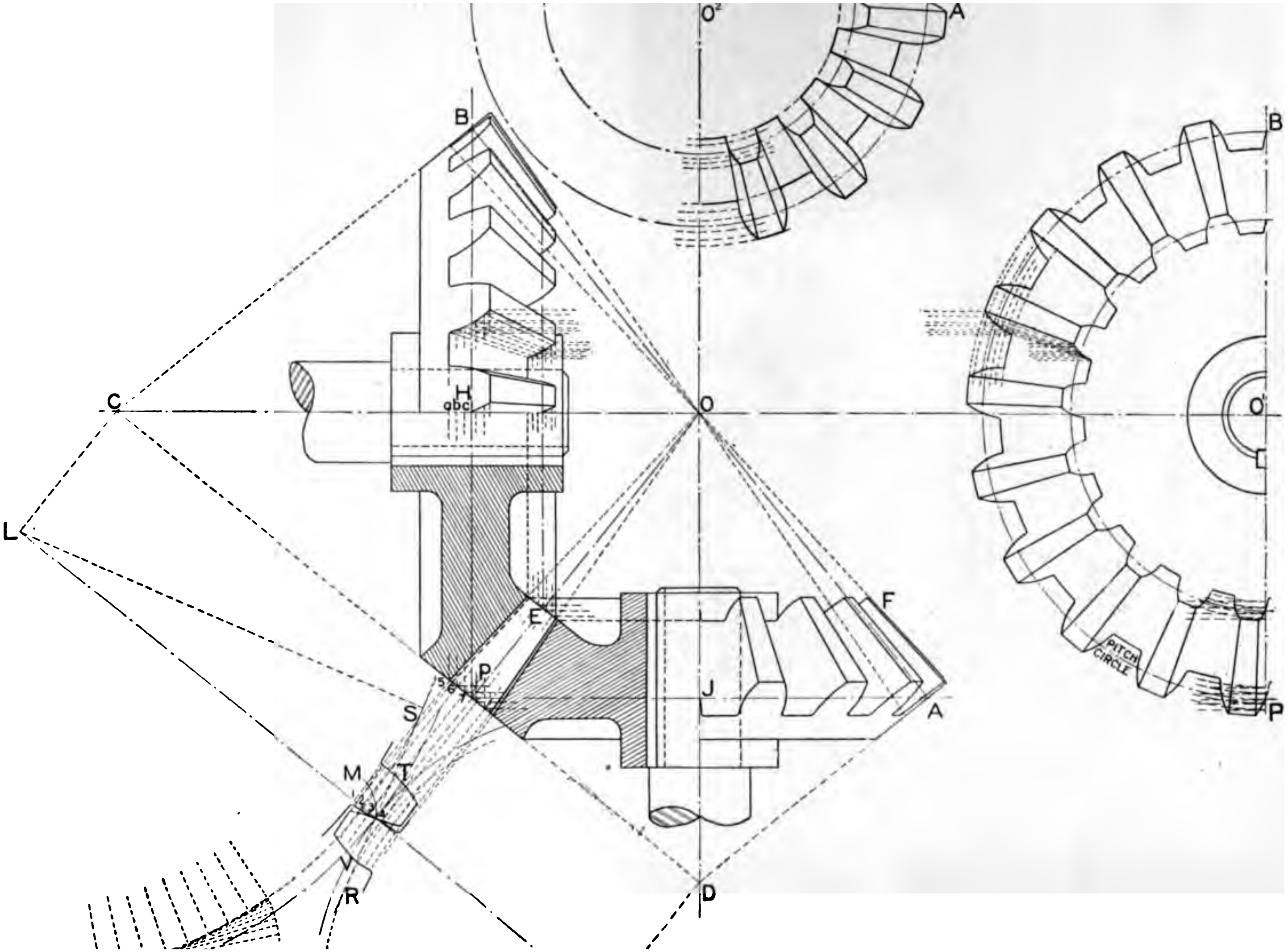



Fig. 63.



O²
A
B
B
O
O¹
C
H
abc
L
E
F
P
5 6 7
S
J
A
PITCH CIRCLE
P
M
T
V
R
D

**Bevel Gears.** When two shafts whose axes intersect are to be connected by gears, the gears commonly used are called bevel gears. The theoretically correct pitch surface of a bevel gear is a part of the sector of a sphere, but as the designing and making of such a gear is somewhat difficult, a cone is substituted for a sphere. Fig. 64 shows a pair of bevel gears connecting two shafts

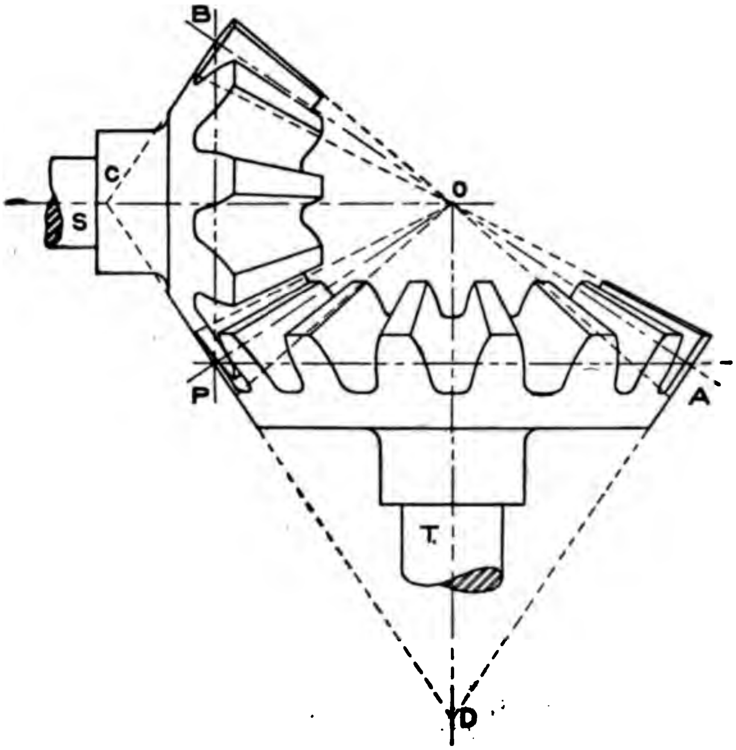
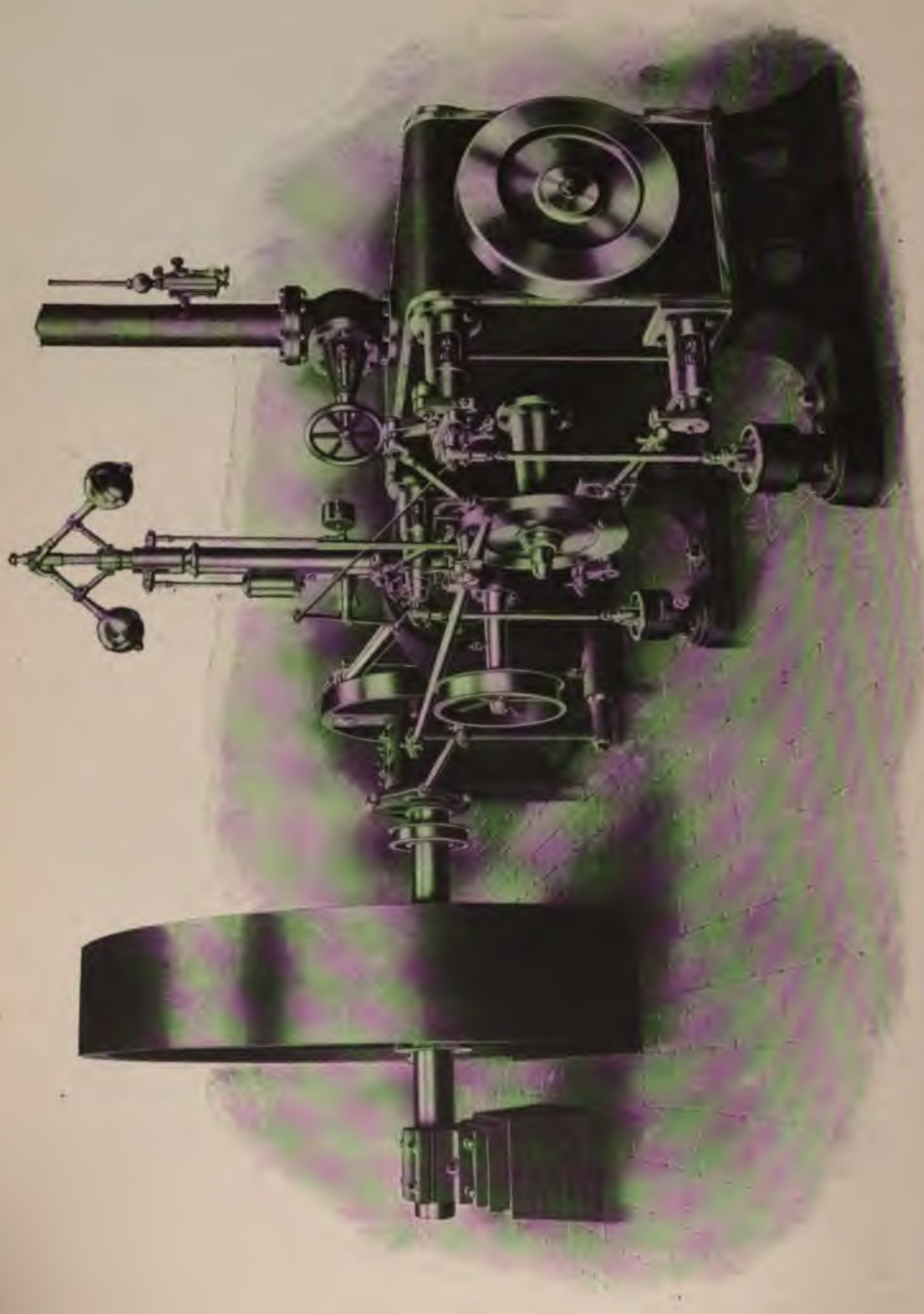



Fig. 64.

which are at right angles. O is the point where the center lines of the shaft intersect, OPA and OPB are the *pitch cones* of the gears, AP and BP the pitch diameters.

The speed of the shaft S is to the speed of the shaft T as AP is to BP. The teeth may be epicycloidal or involute, and the shafts may be at right angles or at some other angle.



MONARCH CORLISS ENGINE.
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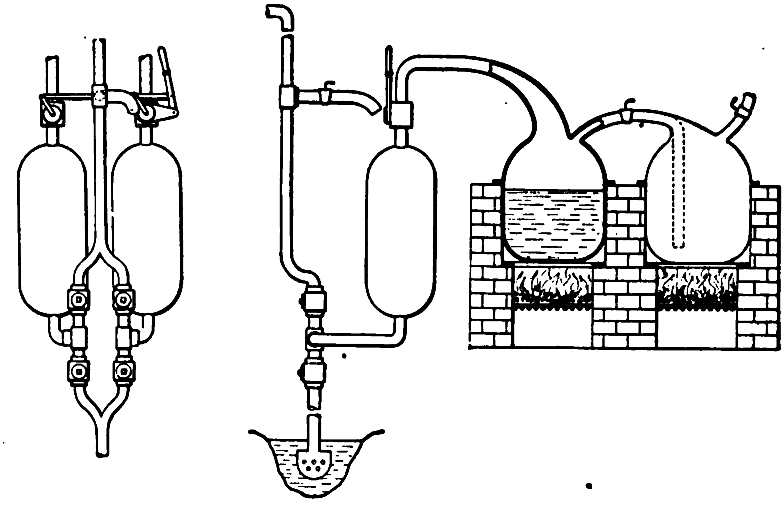
# THE STEAM ENGINE.

There are various kinds of engines from which mechanical work is obtained by the expenditure of heat. In the gas engine a mixture of gas and air is burned in the cylinder, the heat thus generated being converted into work by the expansion of the products of combustion. The action in oil and hot-air engines is very similar. The most important of all heat engines, however, is the steam engine, in which the heat in steam is transformed into work. It will be useful to review briefly some of the stages through which it has passed in its development.

The first steam engines of which we have any knowledge were described by Hero of Alexandria, in a book written two centuries before Christ. Some of them were very ingenious, but the best were little more than toys. From the time of Hero until the seventeenth century there was very little progress. At this time there began to be great need of steam pumps to remove water from the coal mines. In 1615, Salomon de Caus devised the following arrangement. A vessel, having a pipe leading from the bottom, was filled with water and then closed. Heat applied to the vessel caused steam to be formed, which forced the water through the pipe.

A little later an engine was constructed in the form of a steam turbine; but it was unsuccessful, and the attention of inventors was again turned to pumps.

Finally Thomas Savery completed, in 1693, the first *commercially successful* steam engine. It was very wasteful of steam as compared with our engines of today, but as being the first engine to accomplish its task it was a grand success. Savery's engine (Fig. 1) consisted of two oval vessels placed side by side and in communication with a boiler. The lower parts were connected by tubes fitted with suitable valves. Steam from the boiler was admitted to one of the vessels and the air driven out. The steam was then condensed and a vacuum formed by letting water play over the surface of the vessel. When the valve opened, this vacuum drew water from below until the vessel was full. The valve was then closed and steam again admitted, so that on opening the second valve the water was forced out through the delivery pipe. The two vessels worked alternately. When one was filling with water, the other was open to the boiler and was being emptied. Of the two boilers, one supplied steam to the oval vessels and the other was used for feeding water to the first boiler. The second boiler was filled while cold and a fire lighted under it. It then acted like the vessel used by Salomon de Caus and forced a supply of feed water into the main boiler.



END VIEW. Fig. 1. SIDE VIEW.

A modification of Savery's engine, the pulsometer (Fig. 2), is still quite common. It is used in places where an ordinary pump could not be used and where extreme simplicity is of especial advantage. Its valves work automatically and it requires very little attention.

A serious difficulty with Savery's engine resulted from the fact that the height to which water could be raised was limited by the pressure which the vessels could bear. Where the mine was very deep it was necessary to use several engines, each one raising the water a part of the whole distance. The consumption of coal in proportion to the work done was about twenty times as great as that of a good modern steam engine. This was largely, though not entirely, due to the immense amount of steam which was wasted by condensation when it came in contact with the water in the oval vessels.

The next great step in the development of the steam engine was taken by Newcomen, who in 1705 succeeded in preventing contact between the steam and the water to be pumped, thus diminishing the amount of steam uselessly condensed. He introduced the first successful engine which used a piston working in a cylinder.

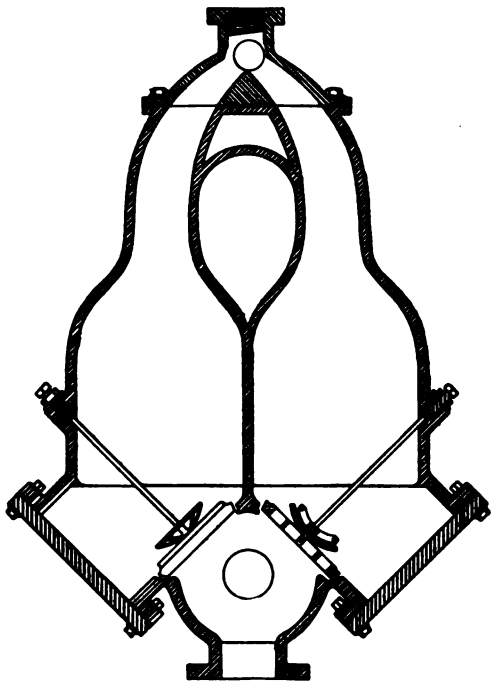


Fig. 2.

In Newcomen's engine, shown in Fig. 3, there was a horizontal lever pivoted at the center and carrying at one end a long heavy rod which connected with a pump in the mine below. A piston was hung from the other end of the lever, and worked up and down in a vertical cylinder, which was open at the top. Steam acted only on the lower side of the piston. Steam at atmospheric pressure was admitted from the boiler to the cylinder, and as the pressure was the same both above and below the piston, the falling of the heavy pump rod raised the piston. A jet of water was now passed into the cylinder to condense the steam and form a vacuum. This left the piston with atmospheric pressure above and very slight pressure below, so it was forced down and the pump rod again raised. Steam could again be admitted to the cylinder, the pump rod would fall, and so on indefinitely.

In the days of Newcomen it was very difficult to obtain good workmanship. For this reason it was often necessary to make the cylinders of wood, and even then there might be a space of one-eighth of an inch between the wall of the cylinder and the piston. In order to prevent steam from blowing through this passage, or air from leaking in when the steam was condensed, it was customary to keep a jet of water playing on the top of the piston.

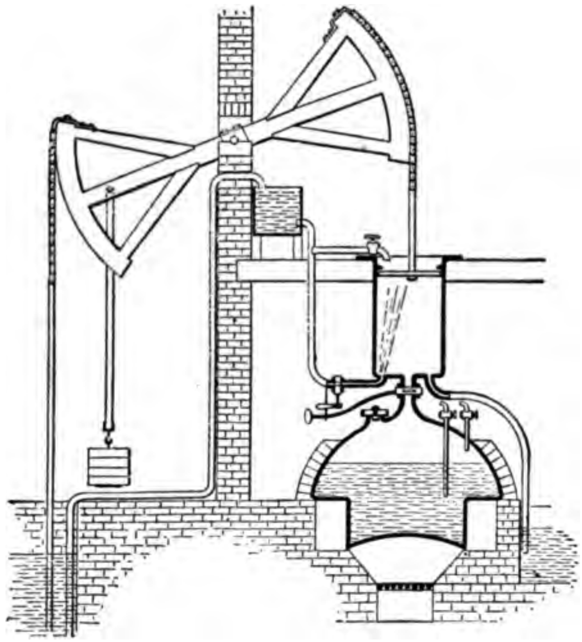


Fig. 3.

One great trouble with all these engines was that they required some one to open and close the cocks. Boys were generally employed to do this work. In order to get time to play, one of them rigged a catch at the end of a cord which was attached to the beam overhead. This did the work for him. Making the valves automatic in this way made it possible to dispense with the services of the boy and at the same time greatly increase the speed of the engine. This engine was improved slightly from time to time by different inventors and was very extensively used until

Watt's time. Some of them are in existence today. While this engine was a success and a great improvement over its predecessors, it was still very large, wasteful and heavy, in comparison with the work done. When the cylinders were made of iron they were simply cast and not bored, thus leaving a rough, stony coating over the iron, called the skin.

In the year 1763, a small model of a Newcomen engine was taken to the shop of an instrument maker in Glasgow, Scotland, to be repaired. This instrument maker, whose name was James Watt, had been studying steam engines for some time and he became very much interested in this model. He was a man of great genius, and before he died his inventions had made the steam engine so perfect a machine that there has been but one really great improvement in it since his time; namely, compound expansion. All other improvements have been merely following in the line of his suggestions and constructing what he could not for lack of good tools.

He found that to obtain the best results it was necessary, "*First, that the temperature of the cylinder should always be the same as that of the steam which entered it; and, secondly, that when the steam was condensed it should be cooled to as low a temperature as possible.*" All improvements in steam-engine efficiency have been in the direction of a more complete realization of these two conditions.

In order to keep the cylinder nearly as hot as the entering steam, Watt no longer injected water into the cylinder to condense the steam, but used a separate vessel or condenser. He made his piston tight by using greater care in construction, so that it was not necessary to have a water seal at the top. He then covered the top of the cylinder to prevent air from cooling the piston. When this was done he could use steam above as well as below the piston; this made the engine double acting.

Also, in the effort to keep the cylinder as hot as the entering steam, he enclosed the cylinder in a larger one and filled the space between with steam. This was not often done, however, and only of late years has the steam jacket been of much advantage. He also used steam expansively, that is, the admission of steam was stopped when the piston had made a part of the stroke; the rest of the stroke was completed by the expansion of the steam already admitted. This plan is now used in all engines that are built for economy.

Other inventions made by Watt on his steam engine were: a parallel motion, that is, an arrangement of links connecting the

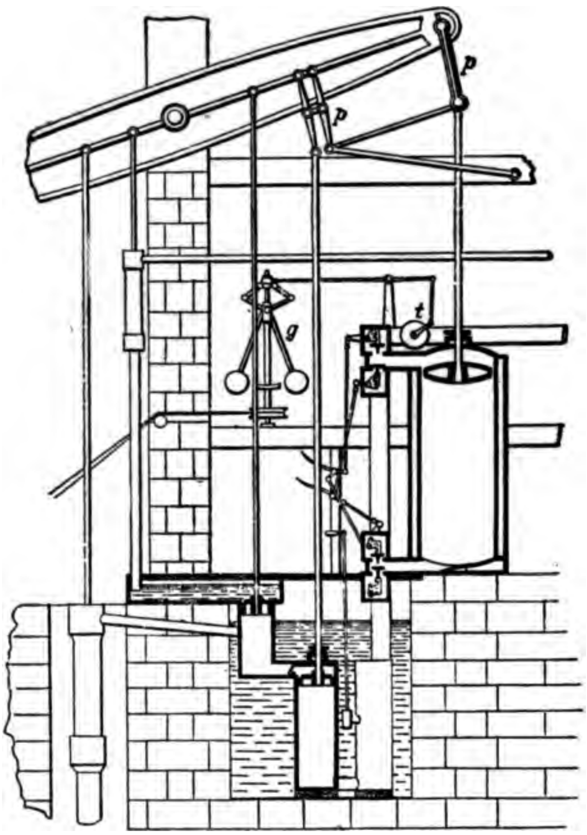



Fig. 4.

end of the piston rod with the beam of the engine in such a way as to guide the rod almost exactly in a straight line; the throttle valve, for regulating the rate of admission of steam and the centrifugal governor, which controlled the speed by acting on the throttle valve.

Watt also invented the "indicator," by means of which diagrams are made which show at all points the relation between the pressure in the cylinder and the position of the piston at that instant. His assistant, Murdoch, invented the slide valve as a means of admitting and releasing the steam. Fig. 4 shows Watt's final engine.

Watt, like other early inventors, sold many of his engines to miners, who had been using horses to pump out the mines, and for this reason he rated his engines by the horse-power. Although this term has an historical derivation it has no real significance, and no relation whatever to the power of a horse. It is an established unit for measuring the rate at which work is done. One horse-power is the amount of work necessary to raise 33,000 pounds through one foot in one minute; and we may say that one horse-power is equal to 33,000 foot pounds per minute.

Watt saw that by using high-pressure steam he could get more work from it; but as it was not possible to make very reliable boilers he never used a pressure of more than seven pounds per square inch above the atmosphere. About the year 1800 comparatively high pressures came more into use and the *non-condensing* engine was introduced. In Watt's engine, and all those preceding his, a vacuum was produced in front of the piston by condensing the steam, and either the atmosphere or steam at atmospheric pressure pushed it through the stroke. In the non-condensing engine, using high-pressure steam, the space in front of the piston could be opened to the atmosphere at exhaust, and although the atmospheric pressure resisted its motion the pressure of the steam behind the piston was still greater than that of the air. These engines were much more simple than the condensing engines, as they required no condenser.

About this time what would now be called a compound engine was introduced by Hornblower and later by Woolf. It had two cylinders of different size. Steam was admitted into the smaller cylinder, and then passed over into the larger. The steam expanded a little in the smaller cylinder and much more in the larger one.

A great many attempts were made to build *locomotives*, but they were generally unsuccessful until George Stephenson built his engine, the "Rocket," in 1829. The principal new feature of this engine was the improved *steam blast* for increasing the steam tight by a stuffing box which surrounds the piston rod. Sometimes the piston rod is prolonged beyond the piston and through the front cover. This extension of the piston rod is to

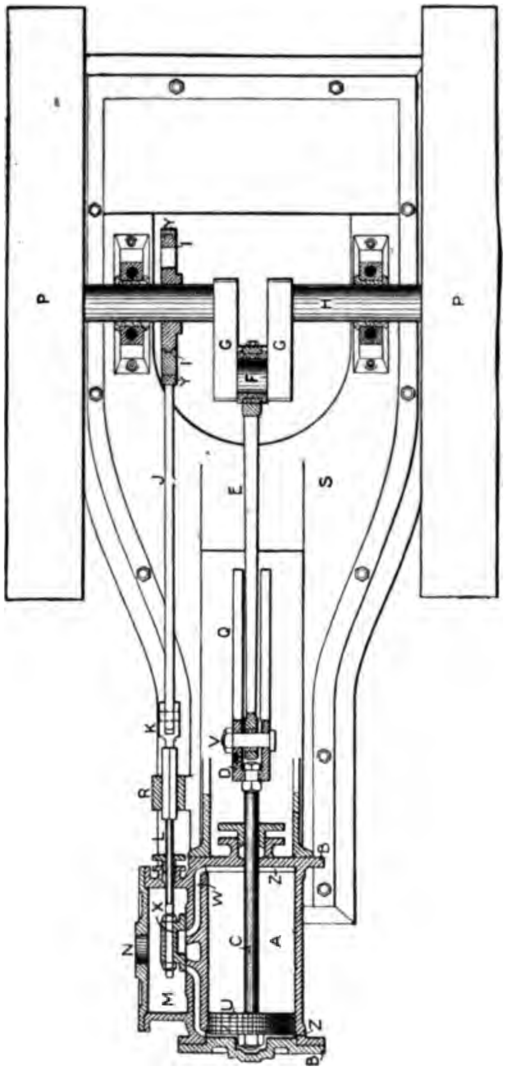


Fig. 6.

help steady the piston in a long stroke and is known as the tail rod. When a tail rod is used another stuffing box must also be provided for the head-end cover.

The Piston U, in small engines, is usually a thick disc of iron or steel, as shown in Fig. 6. It is often made conical, as shown in Fig. 7, to better withstand the steam pressure and to gain space. The piston must fit the cylinder steam tight and yet move easily. To accomplish this, one or more grooves in the piston are filled with packing (usually metallic), or spring rings may be used.

The Piston Rod C (Figs. 5 and 6) is made of steel and connects the crosshead and the piston to which it is rigidly fixed.

The Crosshead D serves to join the piston rod and connecting rod. At one end it is fastened to the piston rod, and at the other end is the wrist pin V on which the connecting rod swings. It is guided to and fro by the crosshead guides Q.

The Connecting Rod E is a steel forging from three to eight times the length of the crank, depending upon the type of engine. One end is jointed to the crosshead by the pin V, called the wrist pin, while the other encircles the crank pin and revolves with it. A detail view of one end is shown in Fig. 8; the other end is frequently similar. In some cases the small end is forked, as shown in Fig. 9.

The Crank Pin F forms the connection between the crank and connecting rod.

The Crank G, equal in length to one-half the stroke of the piston, converts the back and forth motion of the connecting rod into circular motion. It may be simply an arm, as shown in Fig. 10, or a complete disc keyed to one end of the shaft, as shown in Fig. 11. The disc is more nearly balanced than the crank.

The Shaft H transmits the rotary motion from the crank to the fly wheel P.

The Frame of the engine S is a heavy casting, which supports the cylinder and bearings. It should be securely bolted to the foundation.

The Steam Chest M receives steam directly from the boiler, and the steam passes thence through the ports W into the cylinder.

The Eccentric I is a disc keyed to the shaft so that its center and the center of the shaft do not coincide. The eccentric strap Y encircles the eccentric and imparts a reciprocating motion to the valve stem L and the eccentric rod J. This action is similar to that of the crank and connecting rod, but exactly reversed. K is the valve stem crosshead and R its guides.

The Slide Valve X is the valve for alternately admitting

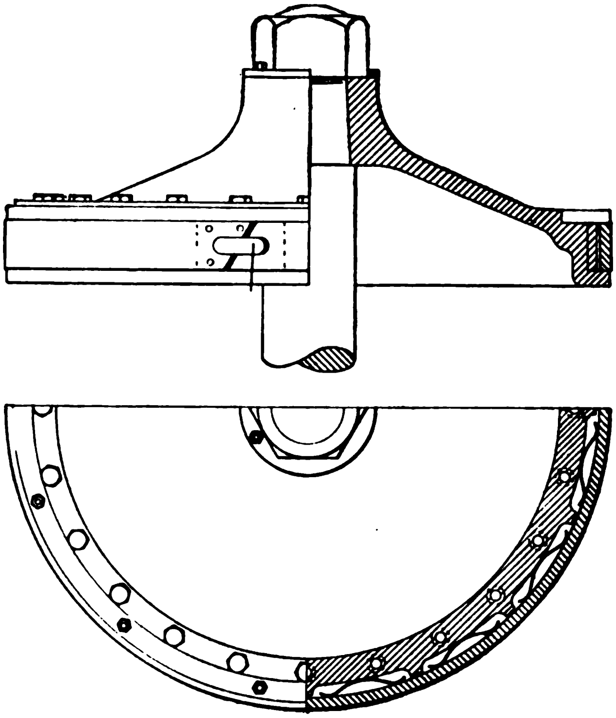


Fig. 7.

steam to the cylinder and releasing it. It has a cup-shaped cavity in its face through which the exhaust steam passes. It is situated in the steam chest and is moved by the valve gear, that is, the eccentric and the eccentric rod.

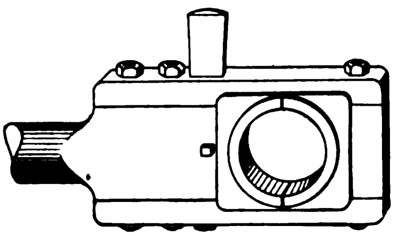


Fig. 8.

The Clearance Z is the space between the piston and the cylinder head (when the piston is at the end of the stroke), together with the volume of the steam ports. This volume must be filled with steam before the piston can start. It is usual to express the clearance as a certain per cent of the volume swept through by the piston.

The crank may revolve in either direction. If we stand by the cylinder, facing the crank shaft, and the crank moves away from us as it passes over the shaft, we say that it is running *over*. If it moves away from us as it passes under the shaft, we say that the engine is running *under*. The action of steam in the cylinder of an engine is very complicated, and its discussion will be taken up later in the course.

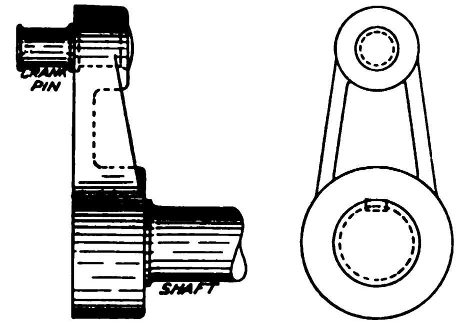



Fig. 10.

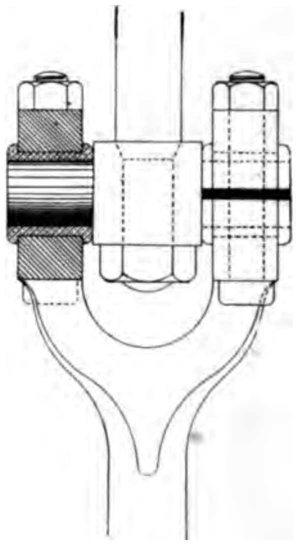


Fig. 9.

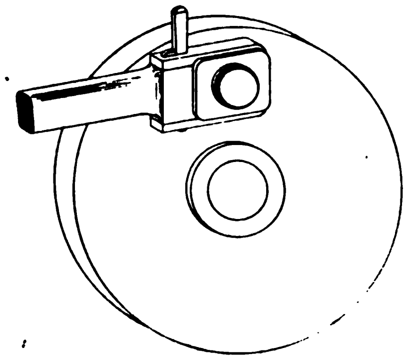


Fig. 11.

## TYPES OF ENGINES.

*Classification.* There are so many different types of engines that it is difficult to classify them all properly. Most engines belong to several classes at one and the same time. For instance, there are condensing and non-condensing engines; there are simple, compound, triple and quadruple expansion; there are high speed and low speed, vertical and horizontal, locomotive, stationary

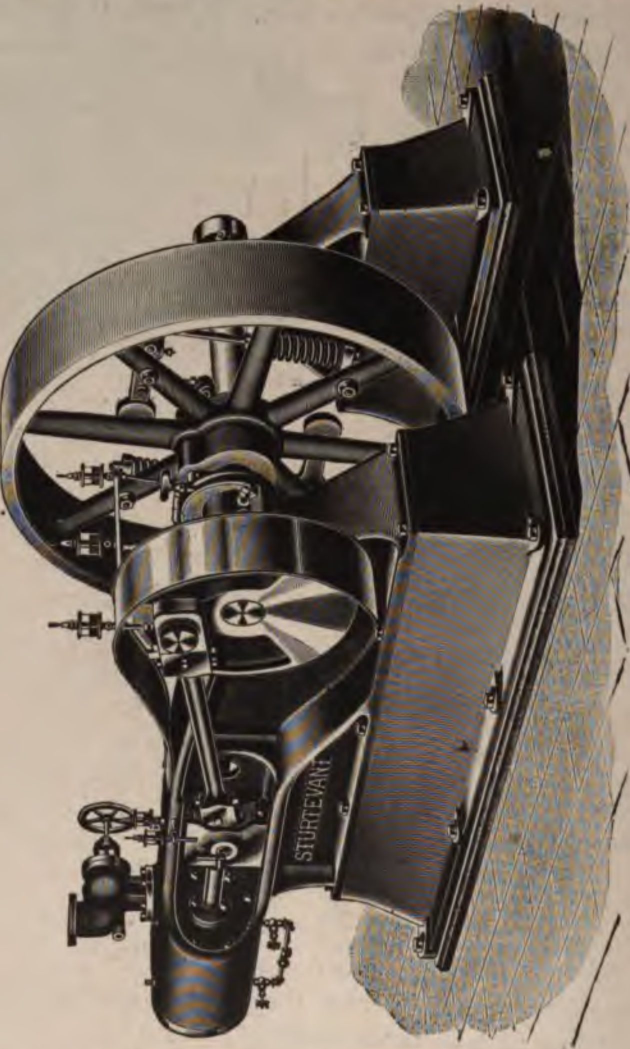
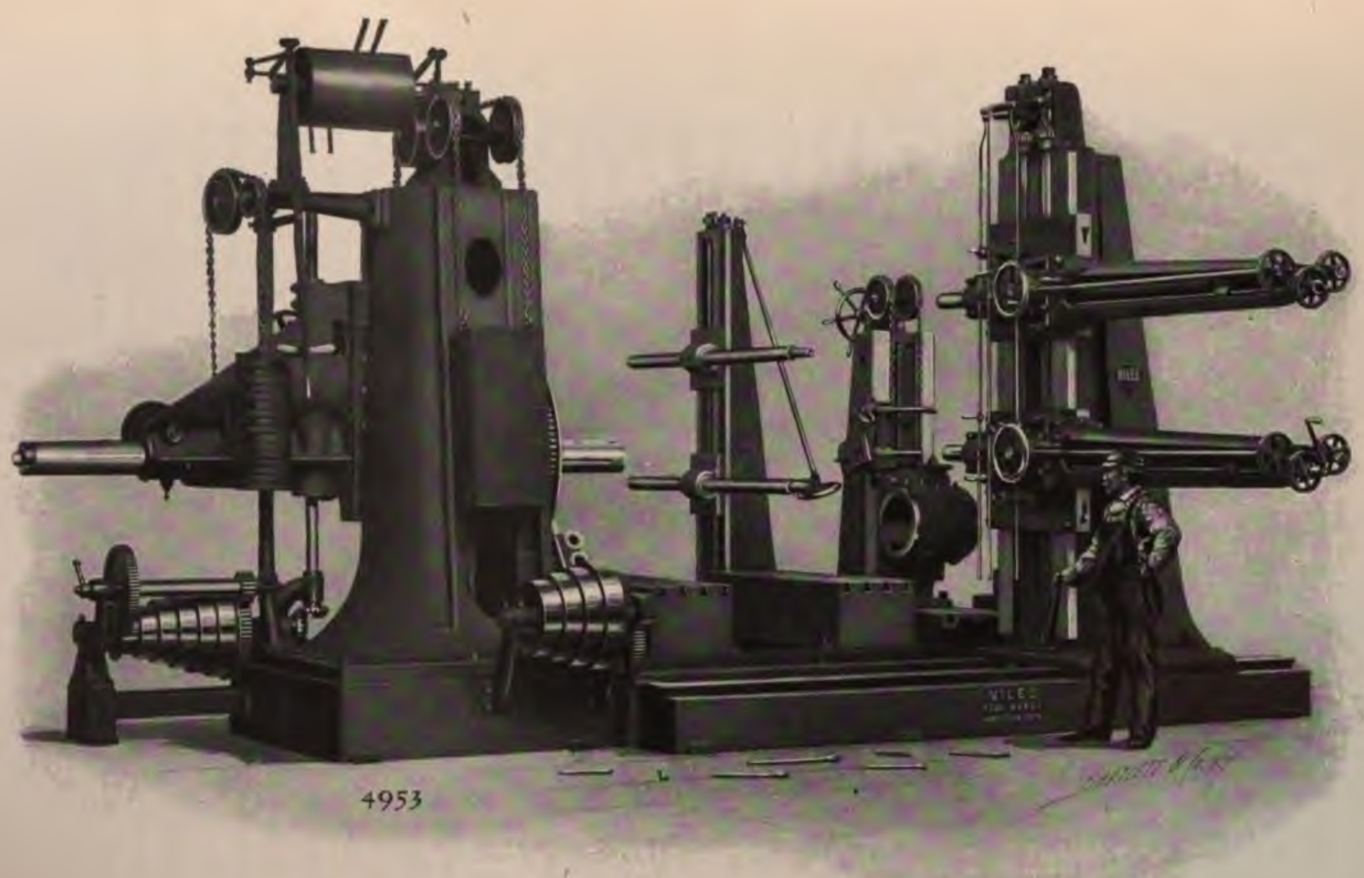



Fig. 12.

and marine, and many other classes into which these might be further subdivided.

*Simple Engines.* The simplest type of engine is the simple expansion. It has one cylinder and admits steam for a part of the stroke, expands it during the remainder and exhausts either into




CYLINDER BORING MACHINE WITH PORT BORING ATTACHMENT.

Niles-Bement-Pond Co.

the atmosphere or into a condenser. Simple engines (see Figs. 5 and 12) are now used only for comparatively small powers, say 100 H. P. or less, and although more extravagant of fuel than the others, may still be the most economical financially if low first cost is an important item, if they are not run continuously, or if the load fluctuates widely.

*Compound Engines* have two cylinders known as the high pressure and low pressure. Steam enters the smaller or high pressure cylinder and then expands until release, when it is exhausted into the larger cylinder, where the expansion is finished. The cylinders should be so proportioned that approximately the same amount of work can be done in each. The first cylinder is small, because it has the higher steam pressure, and a given weight of steam occupies less space when at high pressure. The second must be large, so that the volume at cut-off can contain all of the steam exhausted from the high.

Besides being more economical the compound has a distinct mechanical advantage. The two cranks may be set at right angles, so that when one is on dead center the other is at a position of nearly its greatest effort. This makes a dead center impossible, and gives a more uniform turning moment. Then the individual parts may be made lighter, and are thus more easily handled, but the engine is much more costly, and it is nearly twice as much work to take care of it.

When the cranks of a compound engine are at 90°, the low-pressure piston is not ready to receive steam when the high pressure exhausts, hence there must be a receiver to hold the steam until admission occurs in the low. Such engines are called *cross compound.* Fig. 13 shows one form. Sometimes instead of having the cranks at 90°, they are placed together or opposite. Then the strokes begin and end together, and the high can exhaust directly into the low without a receiver. Such engines are called *Woolf engines.* A tandem compound engine, shown in Fig. 14, has both pistons on one rod, the high-pressure piston rod forming the low-pressure tail rod. Such engines are less expensive because there is but one set of reciprocating parts instead of two, but like simple engines they have the disadvantage of dead points.

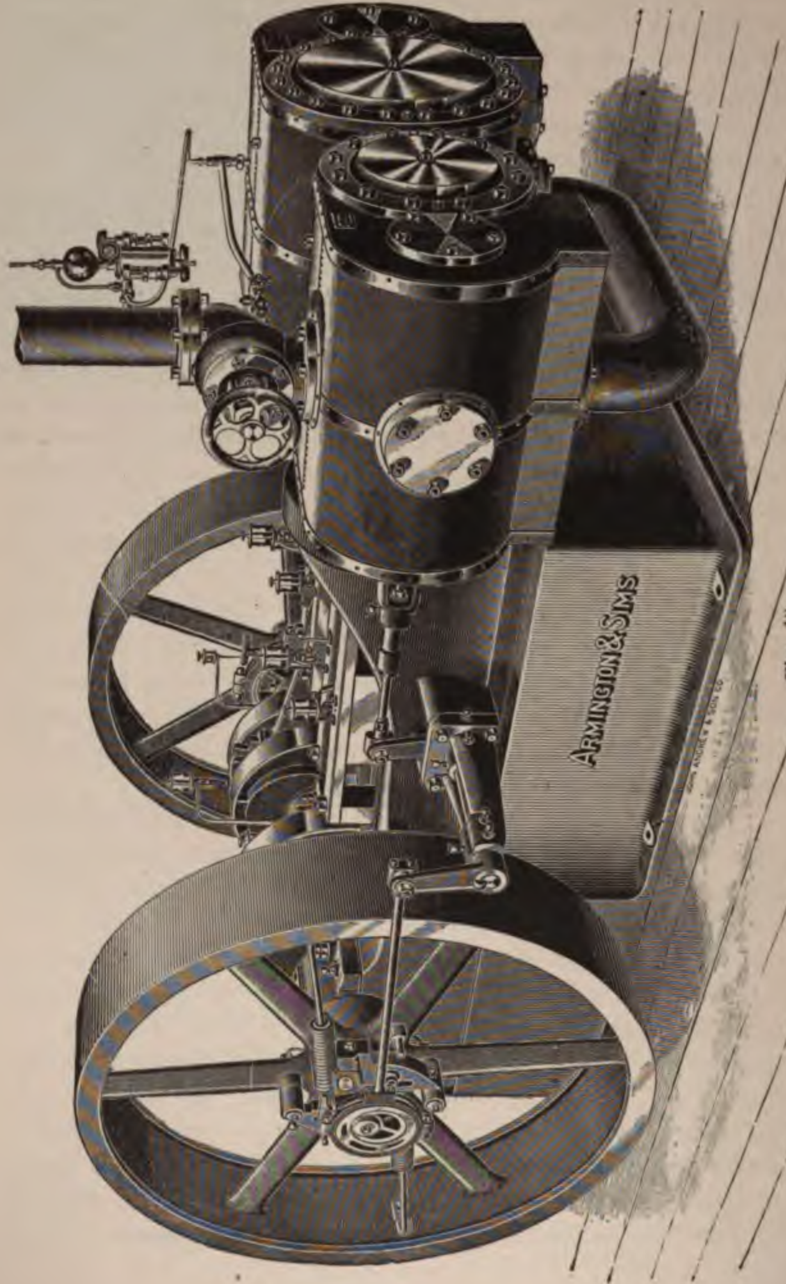



Fig. 13.

*Triple Expansion Engines* expand the steam in three stages instead of two. There are usually three cylinders, the high, intermediate, and low, arranged with cranks 120° apart. This gives a more uniform turning moment than a compound. Sometimes there are four cylinders to the triple, one high, one intermediate, and two low. This arrangement gives better balance and is often used in marine work.

For triple engines there must be a receiver between each two cylinders. Fig. 15 shows the essential features of a triple expansion engine.

*Quadruple Engines* expand their steam in four stages instead of three. Multiple-expansion engines are nearly always condensing.

*Cylinder Ratios.* There are several considerations to be remembered when proportioning the cylinders of multiple-expansion engines. The ratio of the cylinders should be such that each develops nearly the same power; the drop in pressure between the cylinders and receivers should be small, and the strains in the cylinders about equal.

There are many formulas in use, some simple, others involving mathematical calculation. A common rule for compound engines is to make the ratio of the cylinders equal to the square root of the total ratio of expansion. Thus if the steam has a ratio of expansion of 9, the ratio of the cylinder volumes will be $\sqrt{9} = 3$, or the low-pressure cylinder will have a volume 3 times as great as the high-pressure cylinder. If the cylinder ratio is 3, and the length of stroke is the same for both, the diameter of the low-pressure cylinder will be 1.75 times that of the high-pressure cylinder.

Another rule is to make the cylinder ratio equal to the total ratio of expansion multiplied by the fractional part of the stroke completed when cut-off occurs in the high-pressure cylinder.

Suppose the ratio of expansion is 9, as above, and that cut-off occurs at $\frac{1}{3}$ of the stroke in the high-pressure cylinder. The ratio of cylinder volumes will be $9 \times \frac{1}{3} = 3$. If cut-off occurs at $\frac{1}{2}$ the stroke, the ratio will be $9 \times \frac{1}{2} = 4.5$.

For triple expansion engines the low pressure cylinder is made large enough to develop the whole power if steam at boiler pressure is used.

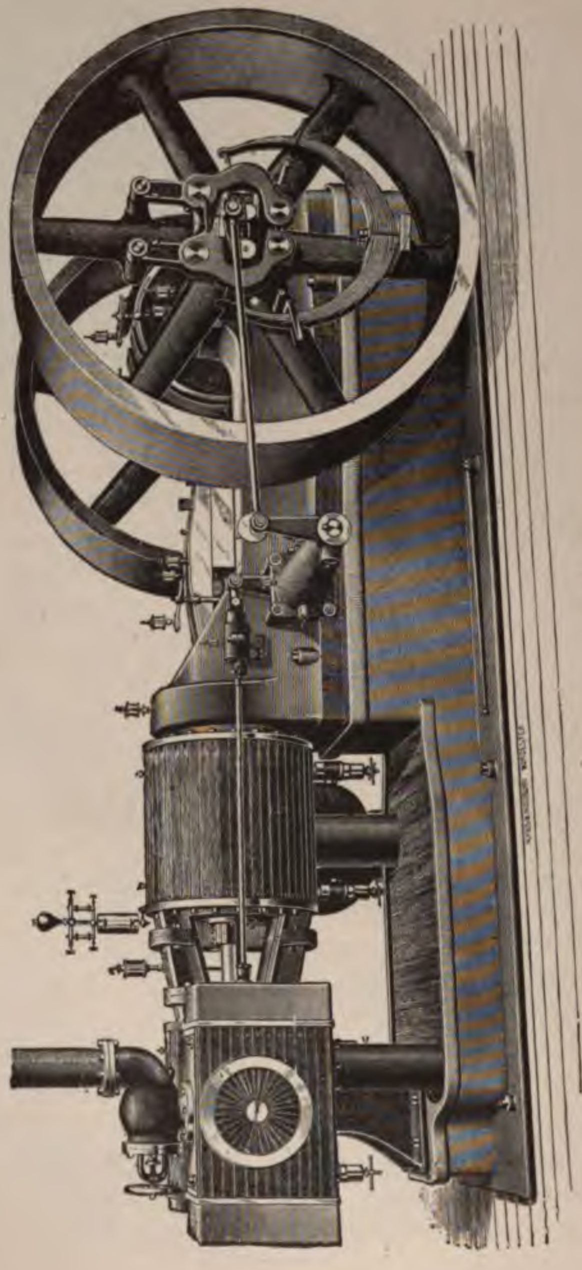


Fig. 14.

The intermediate cylinder is made approximately of a mean size between the high and the low. The area of the intermediate piston is found by dividing the area of the low by 1.1 times the square root of the ratio of the low to the high.

We may write the above thus,

$$\text{Area of high-pres. cyl.} = \frac{\text{Area of low-pres. cyl.}}{\text{Cut-off of high-pres.} \times \text{ratio of exp.}}$$

$$\text{Area of inter. cyl.} = \frac{\text{Area of low-pressure cylinder.}}{1.1 \times \sqrt{\text{ratio of low to high.}}}$$

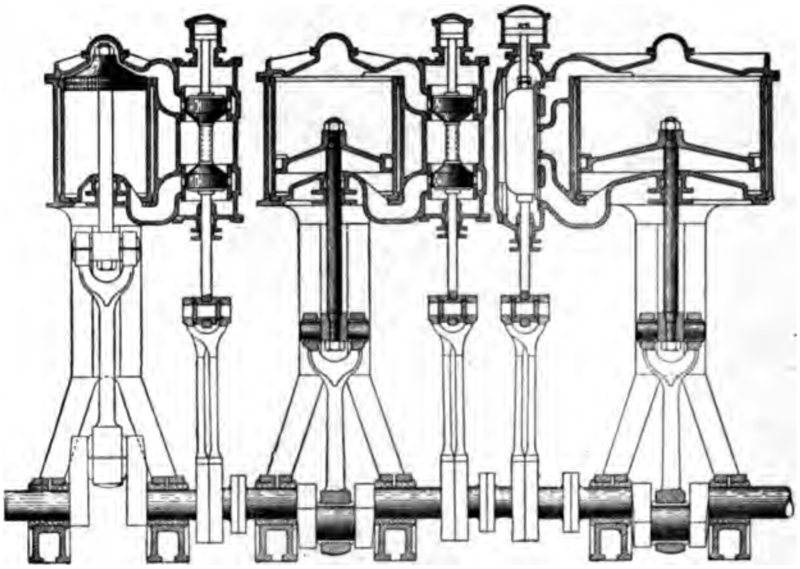


Fig. 15.

In general the volumes for triple expansion are of about the following ratios, 1 representing the volume of the high pressure cylinder:

1 : 2.25 to 2.75 : 5 to 8.

For quadruple-expansion engines the ratios are as follows:

1 : 2 to 2.33 : 4 to 5 : 7 to 12.

*High Speed Engines.* Of late years there has been a demand for engines of higher speeds than were formerly used. It was found desirable to run dynamo-electric machines by connecting them *directly* to the shaft of the engine rather than by belts as before.

This required engines running from 200 to 1,000 revolutions per minute instead of from 60 to 90 revolutions. Also for engines in

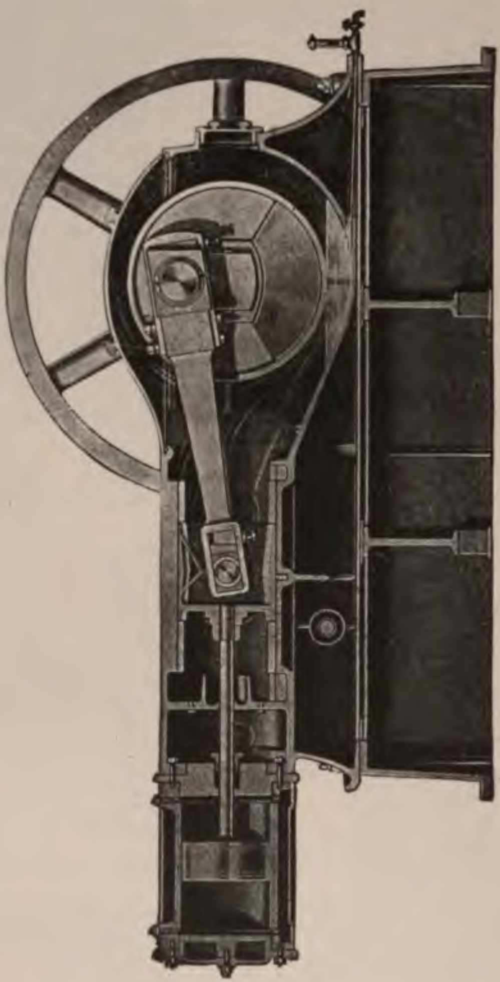


Fig. 16.

torpedo-boats, speeds as high as 400 or 500 revolutions are common.

Running at high speed requires various changes. Reciprocating parts must be made lighter to reduce the vibration, and must be more carefully proportioned to maintain balance. Bearings must be made very much larger to reduce the pressure in order that the friction may not be excessive and cause heating. Special care is necessary that bearings should be tight, since the least looseness will cause knocking and hammering until the bearing is ruined. Parts must be as simple as possible and so arranged as to need the least possible attention. In slow-speed engines the engineer can watch the oil cups and oil any part while it is running. But this is impossible in high-speed engines, and special means must be used to insure plenty of oil to the bearings and the cylinder.

These peculiarities of high-speed engines may be easily seen in any engine for electric lighting, for running fans, etc. It is also necessary that the speed of engines for running electric generators should be very steady, as the slightest change in the speed make the lights flicker. The fly wheels are, therefore, larger or heavier than for other types and the governors are made specially sensitive. Fig. 16 shows a horizontal high-speed engine with the working parts encased. Fig. 17 shows a vertical high speed.

For any *double-acting* engine, that is, for any engine in which the steam acts first on one side and then on the other side of the piston, the piston first pushes and then pulls on the connecting rod and crank. At each half revolution of the crank the direction of the pressure reverses. It is this change of pressure which causes the pounding if the bearings are at all loose. This is one of the greatest troubles with high-speed engines. In order to avoid these rapid reversals in pressure, *single-acting* vertical engines are used to a considerable extent. In such engines the steam is admitted only to the *head end* of the cylinder. The other end stands open. The connecting rod is in compression throughout the whole revolution instead of being first in compression and then in tension. Besides insuring that the piston shall always push, this arrangement simplifies the valves.

There are several good single-acting, high-speed engines. One of the earliest made was introduced by Brotherhood. He used three cylinders, set around the shaft 120° apart. Another well-known example is the Willans "central valve" engine. These are both English engines. A well-known American engine of this type is the Westinghouse high-speed engine, a section of which is shown in Fig. 18.

*Vertical and Horizontal Engines.* At the present time the most common type of engine is the horizontal direct-acting, that

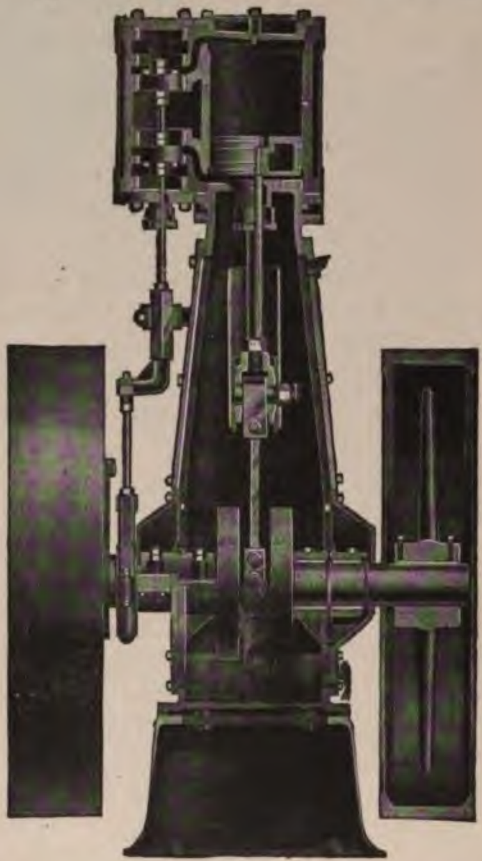


Fig. 17.

is, an engine whose cylinder is horizontal and whose piston acts on the crank through a piston rod and connecting rod. In small engines the whole is often on one bed plate. Such engines are called self contained. The cylinder is either bolted to the back of the bed plate or rests directly on it.

In marine work vertical engines are used in almost every case. The reason for this is, of course, the saving of floor space, which is so important in a vessel. This saving of space, however, is also very important in many cases such as in crowded engine rooms of cities where land is expensive, and as there are a number of advantages which vertical engines have over horizontal, they are coming largely into use in stationary practice.

A second advantage of the vertical over the horizontal engine is the reduction of cylinder friction and unequal wear in the cylinder of the latter. In the horizontal engine the piston is generally supported by resting on the cylinder, which is gradually worn until it is no longer round. This causes leakage of steam from one side to the other. Evidently this is entirely avoided in the vertical engine.

Still another advantage of the vertical engine is the greater ease of balancing the moving parts so that there shall be no jarring or shaking. It is impossible to perfectly balance a steam engine of one or two cylinders. If it is balanced so that there is no tendency to shake sidewise, it will shake endwise; and if it is balanced endwise it will shake sidewise. The jarring is due to the back and forth motion of the reciprocating parts and the centrifugal force of the crank and connecting rod. The crank can be readily balanced by making it extend as far on one side of the shaft as it does on the other, but the piston and connecting rod are more difficult to balance. We can greatly reduce the effect of jarring if we balance the crank and make the endwise throw come in line with the foundation, which should be heavy enough to absorb the vibration transmitted. In a horizontal engine this endwise throw not being in line with the foundation will cause vibration in the engine itself.

In machines that can be anchored down to a massive foundation a state of defective balance only results in straining the parts and causing needless wear and friction at the crank-shaft bearings and elsewhere, and in communicating some tremor to the ground. The problem of balancing is of much more consequence in locomotive and marine engines.

To sum up the general advantages of vertical engines: they have less cylinder wear, they take up less floor space, and they can be better balanced. In addition to these there are certain advantages which vertical engines have for certain kinds of work.

The disadvantages of vertical engines are as follows: The pressure on the crank-pin is greater during the *down* stroke than during the *up* stroke because, during the down stroke the weight of the reciprocating parts is added to the steam pressure, and during the up stroke this weight is subtracted.

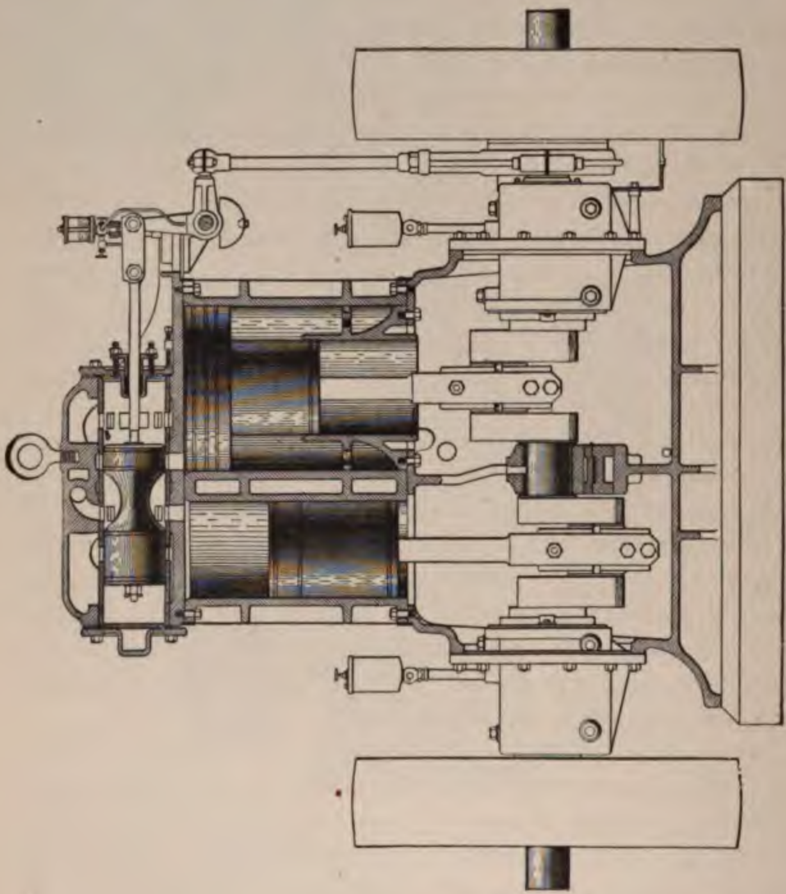


Fig. 18.

Another difficulty is that in large engines the various parts are on such different levels that they require considerable climbing. This requires more attendants and is sometimes the cause for neglect of the engine.

The foundations for vertical engines generally need to be *deeper* than those for horizontal engines. At the same time, however, they need not be as *broad*.

*Marine Engines.* The first steam vessels were fitted with paddle-wheels, and as beam engines were the most common, this form of engine was used. Its construction, however, was somewhat modified for this service. This arrangement of beam engine and paddle-wheel was used for many years and was applied to ocean vessels as well as to small river boats. It is still used, especially in this country, on river steamers and some coast steamers. The beam is supported by large A frames on the deck, and the engines are about on a level with the shaft.

Engines of this type take up rather more room than those now in common use, partly because of great size, and also because of the shaft and paddle-wheels. Another disadvantage is that in heavy weather, when one paddle-wheel is thrown out of water the other is deeply immersed and takes all the strain, so that there is a tendency to rack the boat. Then again if the boat is loaded heavily the paddle-blades are very deeply immersed while if light they barely touch the water. It is hard to handle the engines satisfactorily under both conditions.

The introduction of the screw propeller overcame these difficulties very largely and at the same time required a much faster running engine. At first, the increased speed was supplied by the use of spur-wheel gearing, but gradually higher speed engines were built and connected directly to the propeller shaft. It was, of course, difficult with small width at each side of the shaft to use horizontal engines, therefore various arrangements of inclined engines were used before the vertical engine was finally chosen by all as the standard form for marine work. It is only in recent years that the vertical engine has become general in naval work and in merchant steamers.

In merchant ocean steamers the common form has three cylinders set in line, fore and aft, above the shaft. The cranks are 120° apart, to give a very even turning moment. The three cylinders are worked *triple expansion.* The valves are usually piston valves on the high and intermediate, and double ported slide valves on the low. Sometimes piston valves are used on all the cylinders. Plain slide valves are not suitable for high-pressure work of any kind.

For engines on ocean vessels it is necessary to use surface condensers in order that the same water may be used over and over again. If it were necessary to take in sea-water for the boilers they would soon become clogged with the salt and require cleaning. Surface condensers for marine work are generally made up of a large number of brass tubes of from $\frac{3}{4}$ inch to 1 inch in diameter. In some cases the cold water is forced to flow through the tubes while the steam comes in contact with the outside of the tubes.

In any marine plant there are four special pumps. The *first* is the air pump for the condenser. This is usually made large so that in case there is a leak in the condenser it can take charge of the water even if it becomes necessary to run as a jet instead of a surface condenser. The *second* is the feed pump for the boilers. The *third* is the circulating pump, which forces the current of cold water through the condenser. The last is the bilge pump, which pumps out water that gathers in the bilge of the ship by leakage or otherwise. In case of a serious leak all the pumps can be made to pump from the bilges. In some old types all these pumps were worked from the main engine; generally, however, the feed pump and the circulating pump are separate, as also the bilge pump. The circulating pump is, in many modern engine rooms, of the centrifugal type.

*Locomotive Engines.* Of all steam engines the most inefficient is the steam locomotive. In the first place, the boiler must be forced so hard that the products of combustion pass off at a very high temperature and consequently carry away a great deal of heat. Bits of entirely unburned or partially burned coal are drawn through and wasted.

In the second place, the boiler is exposed to great loss of heat by radiation. Although its surface is lagged, it cannot be very effectively covered, and the wind takes away a great deal of heat.

Mechanically also the locomotive is very imperfect. In most good steam engines the efficiency, that is to say, the ratio of the *effective horse-power* to the *developed horse-power* is fully $\frac{9}{10}$ or 90 per cent. In the locomotive this ratio was shown to be about 43 per cent by two independent tests. This is in part due to the special difficulties in locomotive construction, but the principal losses are those caused by radiation and the escape of heat from the stack.

As to locomotive boilers, Mr. Forney says, "The weight and dimensions of locomotive boilers are in nearly all cases determined by the limits of weight and space to which they are necessarily confined." It may be stated generally that within these limits a locomotive boiler cannot be made too large. In other words, boilers for locomotives should always be made as large as possible under the conditions that determine the weight and dimensions of the locomotives.

There are certain types of locomotives common in American practice which have special names. The eight-wheel or "American" passenger type of locomotive has four coupled driving-wheels and a four-wheeled truck in front. The "ten-wheel" type has six coupled drivers and a leading four-wheel truck. This type is used for both freight and passenger service. The "Mogul" type is used altogether for freight service; it has six coupled drivers and a two-wheel or pony truck in front. The "Consolidation" type is used for heavy freight service. It has eight coupled driving-wheels and a pony truck in front. There are also a great many special types for special purposes. In switch-yards a type of engine is used which has four or six drivers with no truck. The Forney type has four coupled driving-wheels under the engine and a four-wheel truck carrying the water-tank and fuel. This type is used on elevated roads largely. "Decapod" engines are a type used for heavy freight service, having ten coupled driving-wheels and a two-wheel truck in front. A tank engine is one which carries the feed water in tanks on the engine itself instead of in the tender, as in other engines. The various different forms are too numerous even to name.

There has been some effort made to introduce compounding in locomotive practice. It has in some cases been very successful, especially for express trains. A committee of the American Railway Master Mechanics Association says of compounding:

"(*a*) It has achieved a saving in the fuel burnt, averaging 18 per cent at reasonable boiler pressures.

(*b*) It has lessened the amount of water to be handle.

(*c*) The tender can, therefore, be reduced in size and weight.

(*d*) It has increased the possibilities of speed beyond sixty miles per hour, without unduly straining the engine.

(*e*) It has increased the haulage power at full speed.

(*f*) In some classes of engines it has increased the starting power.

(*g*) It has lessened the valve friction per horse-power developed."

A number of other reasons are given in their report.

In opposition to this may be mentioned the extra first cost of the engine and the cost of maintaining a more complicated machine. It is much more work to keep it in repair and many engineers are of the opinion that the saving in fuel is only sufficient to offset these extra expenses. If the engine is running under steady load, the compounding will effect a great saving; but in many parts of the country the load varies constantly, due to grades in the road.

We shall learn later that a compound engine cannot work efficiently under light load. If the grades are first up and then down, the simple engine is the more economical. For a steady up-grade the compound is more economical, as it can be run steadily under full load. This is especially true in mountain districts, where the long up-grades and scarcity of fuel and water make ideal conditions for compound locomotives. Through freight service probably offers the widest field for success with these engines.

It has already been said that it is difficult to balance an engine completely. This defect is very much greater in locomotives than in stationary engines. Lack of balance in a locomotive results in serious pounding of the track. Also there is danger of flattening and breaking the wheels, and the rails may be seriously damaged.

*Pumping Engines.* The first steam engines built were pumping engines and today the most economical engines are those built for this work.

In pumping engines it is not absolutely necessary to have a revolving shaft. All that is required is that the piston in the pump cylinder shall be driven back and forth with a plain reciprocating motion which may be exactly like that of the steam piston. For this reason, in early pumping engines and also in many modern engines, the reciprocating motion of the steam piston is applied directly, or through a beam, to produce the reciprocating motion of the pump piston or plunger without the use of any revolving part. Frequently, however, it is desirable to use a fly wheel so that the steam may be used expansively, and in these cases, of course, a revolving shaft must be used. Fig. 19 shows a power pump.

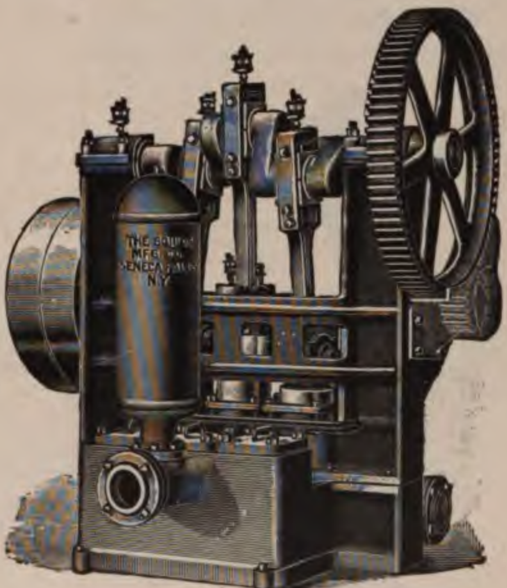


Fig 19.

For deep-well or mine pumping, the cylinders are often set in a vertical position directly over the pump cylinder. The piston rod extends from the steam cylinder directly below to the pump plunger. Sometimes it is possible to use steam expansively in these pumps by reason of the weight of the reciprocating parts. When the weight is sufficient, the steam can be cut off before the end of the stroke and the momentum of the parts will be enough to just finish the stroke, consequently these pumps are sometimes compounded. They are possible only in pumping from very deep wells.

*Direct-acting Steam Pumps.* Fly wheel pumps have one disadvantage, if run too slowly the momentum of the fly wheel is not sufficient to carry it by the dead centers; if run too fast the fly wheel is in danger of bursting. A fly-wheel pump can be made to discharge a small amount of water by means of a bypass valve, but of course it then runs at a disadvantage.

The direct-acting steam pump shown in Fig. 20 has the steam piston at one end of a rod and the water piston at the other end. The steam pressure acts directly on the piston; no fly wheel is used, and since the reciprocating parts are comparatively light, and there is no revolving mass to carry by the dead points, it is evident that in the ordinary form there can be no expansion of steam. The pump is inexpensive and gives a positive action. It uses a great quantity of steam relatively, but for small work the absolute amount is not very great. Even in larger engines the lighter foundations that are possible and the slight first cost are frequently controlling features.

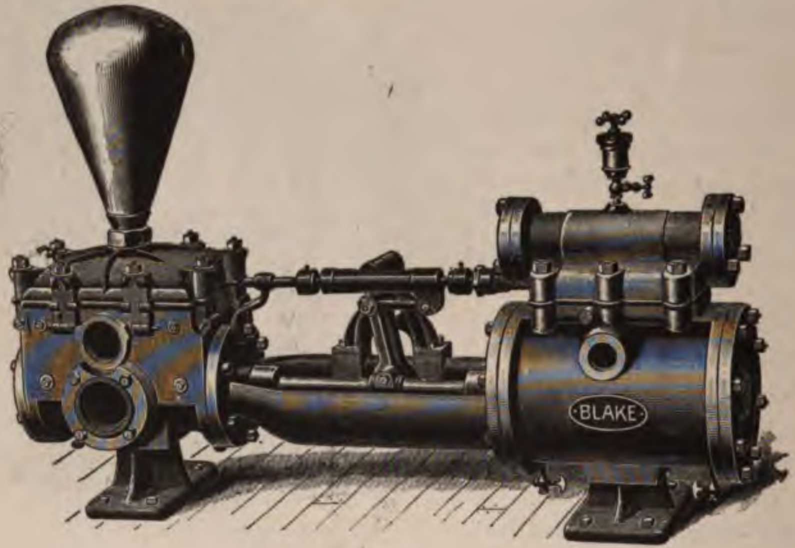
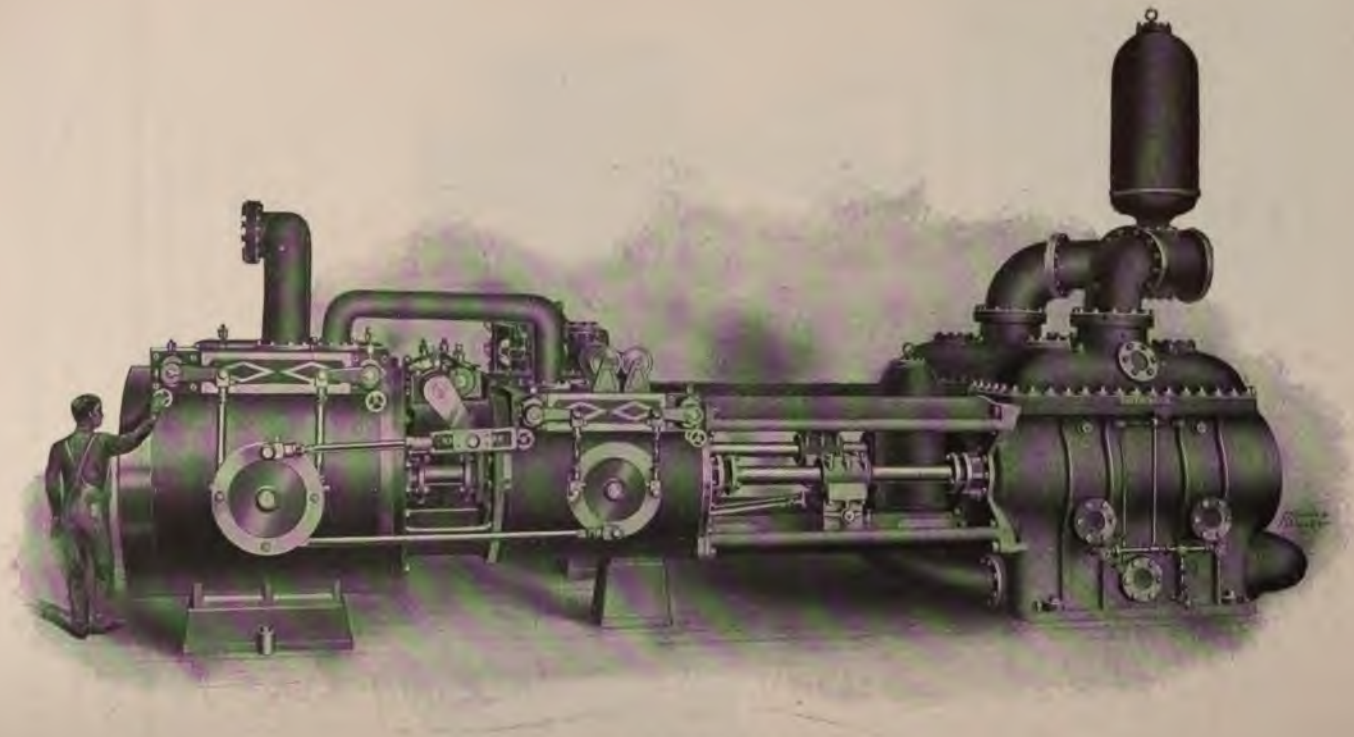



Fig. 20.

A rocker or bell-crank lever on the piston rod moves the steam valve and admits steam to the other side of the piston while opening the first side to exhaust. In large pumps of this kind, and even in some small ones, this motion merely admits steam to a small auxiliary piston which then moves the main steam valve by steam pressure. Some pumps operate the steam valve by means of a tappet instead of a rocker and bell-crank lever.

There have been various devices tried for using steam expansively in these direct-acting pumps without the use of a fly-wheel.



COMPOUND PUMPING ENGINE.
Stillwell-Bierce-Smith-Vaile Co.

In order to do this it is necessary to provide some means of storing energy during the early part of the stroke and returning it during the latter part, when, owing to the expansion, the pressure of the steam is less. One such device is as follows: a crosshead A, (Fig. 21) fixed to the piston rod is connected to the plungers of a pair of oscillating cylinders B B, which contain water and communicate with a reservoir full of air compressed to about 300 pounds per square inch. When the stroke (which takes place in the direction of the arrow) begins, these plungers are first forced in, and hence work is at first done on the main piston rod, through the compensating cylinders B B, on the compressed air in the reservoir. This continues until the crosshead has advanced so that the oscillating cylinders stand at right angles to the line of stroke. Then for the remainder of the stroke their plungers

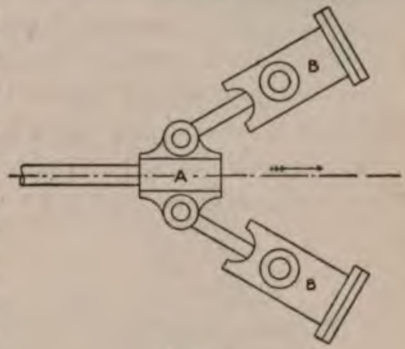



Fig. 21.

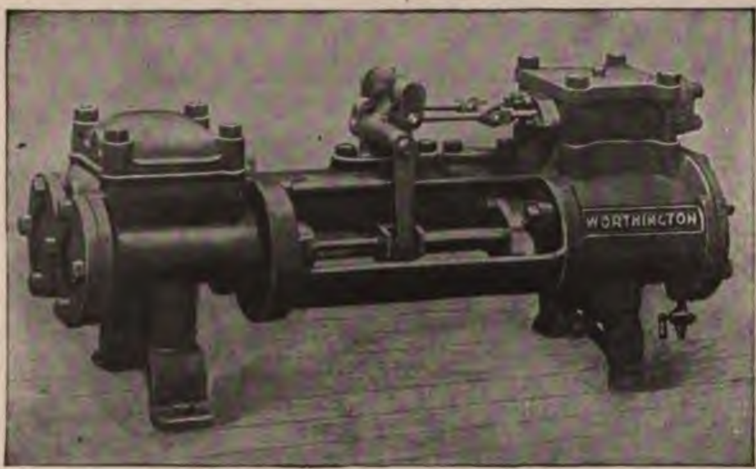



Fig. 22.

assist in driving the main piston, and the compressed air gives out the energy which it stored in the earlier portion.

*The Duplex steam pump* consists simply of two direct-acting steam pumps placed side by side, as shown in Fig. 22. On the piston rod on one side is a bell-crank lever which operates the valve of the other pump. On the further piston rod is a rocker arm which moves the valves of the first pump. There must be a rocker on one side and a bell-crank lever on the other because of the relative motion of the valves and pistons. The first piston, as it goes forward, must use a rocker because it draws the second valve back. The second piston, as it goes back, must use a bell-crank lever because it must push the first valve back in the same direction as its own motion. The two pistons are made to work a half-stroke apart. Thus one begins its stroke when the other is in the

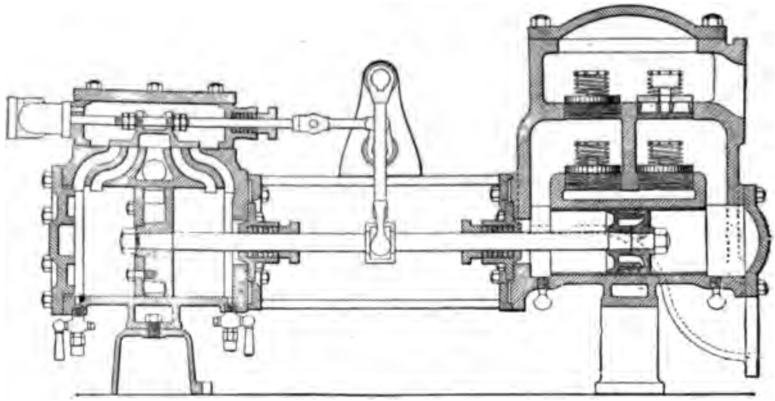


Fig. 23.

middle. In this way a steadier flow of water is obtained, for both pumps discharge into the same delivery pipe. The pumps may be made compound. A sectional view of the pump is shown in Fig. 23.

*Corliss Engines.* In large engines a common way of regulating the steam supply is by changing automatically the point in the stroke of the piston at which the steam is cut off. This is frequently accomplished by using some trip gear similar to the one first introduced by Geo. Corliss. These gears are called Corliss gears. In the Corliss gear there is a separate admission valve and a separate exhaust valve for each end of the cylinder, as shown in Fig. 24. The exhaust valves are opened and closed by the motion of rods or cranks connected to them. The admission valves are opened in the same way, but they snap shut by themselves when the piston has reached a certain point of its stroke. This point will vary with the position of the governor, which in turn depends on the speed of the engine. These Corliss engines cannot be run at high speed because the trip gear requires some time to act.

The valves of Corliss engines turn in hollow cylindrical seats which extend across the cylinders. A wrist plate which turns on

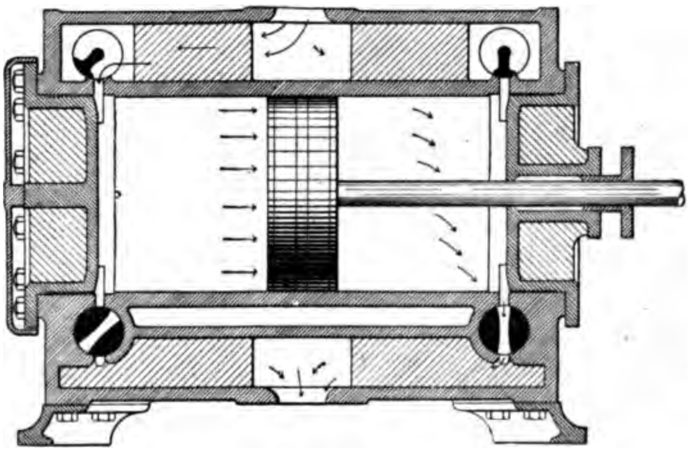


Fig. 24.

a pin on the outside of the cylinder receives a motion of oscillation from an eccentric and opens the valves by means of the rod connections. When the piston has reached a point where the steam should be cut off, the trip gear is held in such a position by the governor that it releases the valve, which now springs shut under the action of the dash-pot. The admission valve to the other side of the cylinder is controlled in exactly the same way.

The admission valves are generally placed at the top and the exhaust valves at the bottom of the cylinder. Any water which may be formed by steam condensing can readily drain off by this arrangement. There are a great many modifications of the Corliss gear. Fig. 25 is a Harris Corliss Engine.

The advantage of the Corliss gear is the great range through

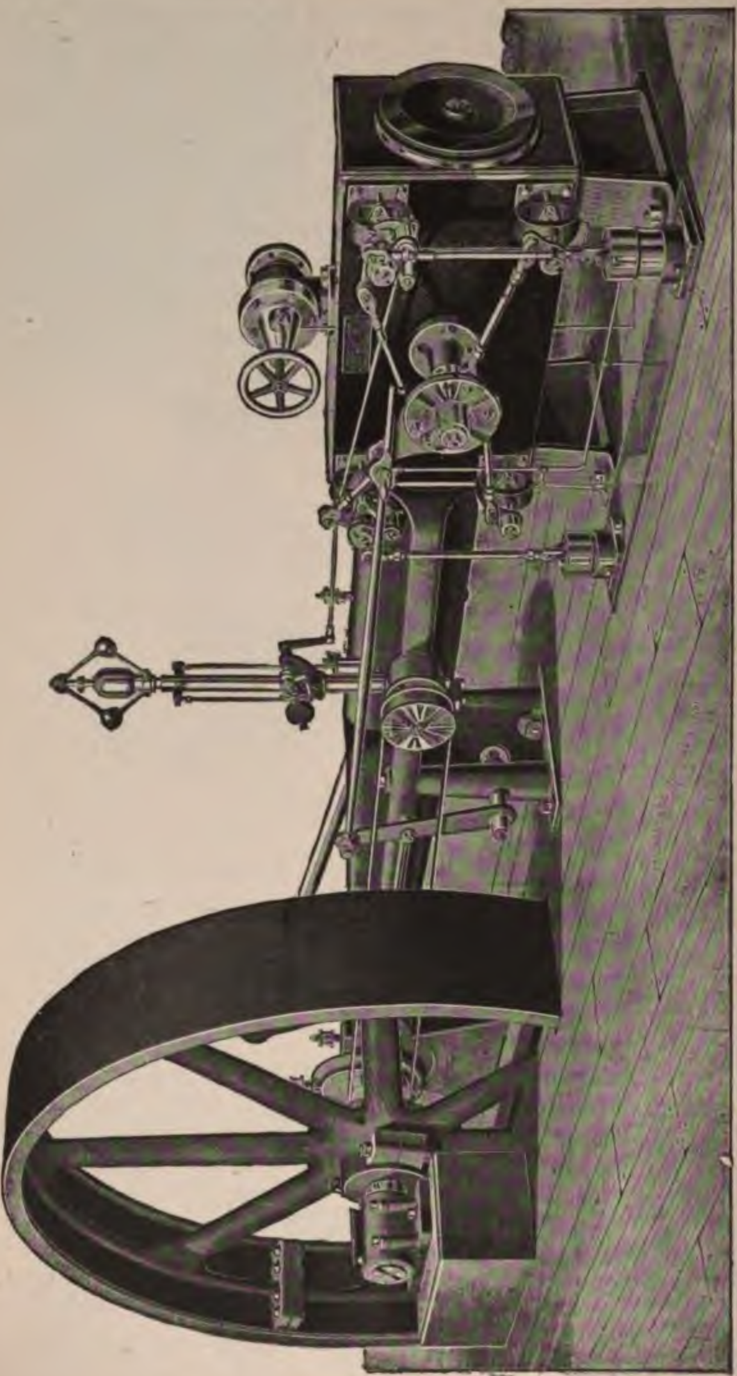


Fig. 25.

which the cut-off can be varied, from very early to very late in the stroke. Another great advantage is the quick action which reduces wire-drawing. To understand fully the loss caused by wire-drawing requires a knowledge of higher mathematics.

### CONDENSERS.

When low-pressure steam is cooled it gives up its latent heat; that is, it changes from a vapor to a liquid. We know that a liquid occupies much less space than an equal weight of vapor; hence, by changing the steam to water the pressure is greatly reduced. By cooling the steam in the cylinder in front of the piston the back pressure, or resistance, is decreased. This reduces the pressure necessary to push the piston through the stroke, therefore less steam is required to do the work. This cooling is accomplished by some form of condenser.

There are two types of condensers, surface and jet. A surface condenser is one in which the steam passes through pipes surrounded by water or the water flows through pipes surrounded by steam. In the jet condenser the steam is condensed by coming in contact with cold water, which enters as spray. In both types the steam is condensed to water and a partial vacuum is formed, because water occupies much less space than does an equal weight of steam. If it were not for the air in the entering steam there would be an almost perfect vacuum. For this reason every condenser is fitted with an air pump to remove this air and the condensed steam.

*Surface Condensers.* The condenser shown in section in Fig. 26 is a common form of the surface type, in which the air pump and circulating pump are both direct acting and are operated by the same steam cylinder. The cold condensing water is drawn from the supply into the circulating or water pump. This pump forces the water up through the valves and water inlet to the condenser. It flows, as indicated by the arrows, through the inner tubes of the lower section, then back through the space between the inner and outer tubes. The water then passes upward and through the upper section, as it did in the lower. It then passes out of the condenser through the water outlet, taking with it the heat it has received from the steam.

The exhaust steam from the engine enters at the exhaust inlet and comes in contact with the perforated plate, which scatters it among the tubes. This method protects the upper tubing from the effect of direct contact with the exhaust steam. The steam expanding in the condenser comes in contact with the cool tubes,

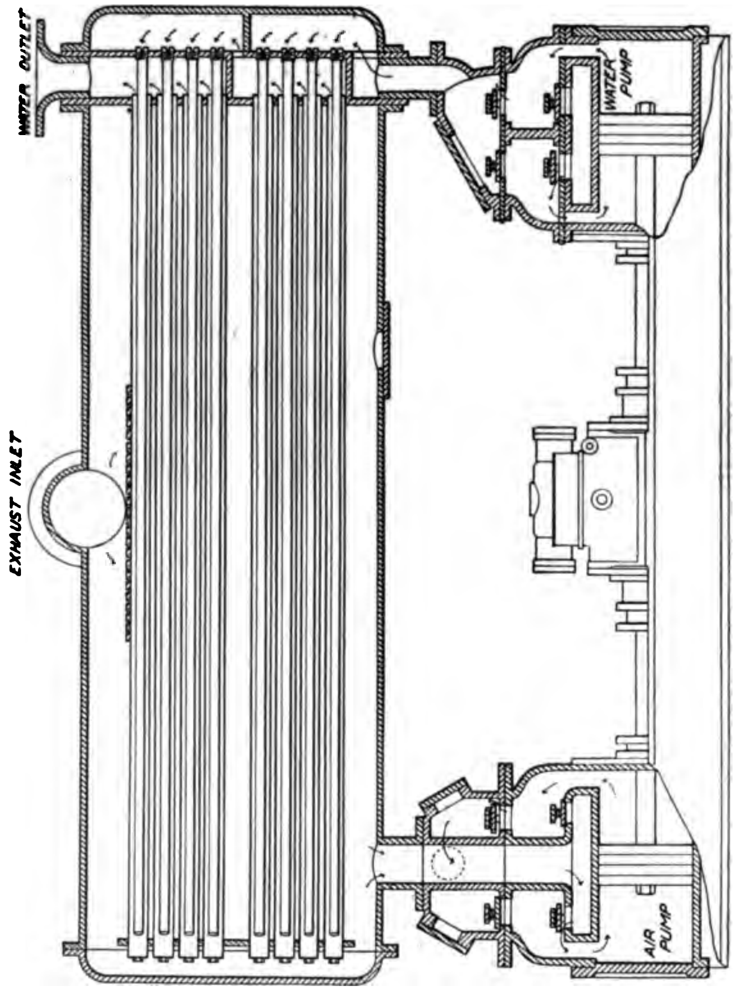



Fig. 26.

through which cold water is circulating, and condenses. The air pump draws the air and condensed steam out of the condenser and thus maintains a partial vacuum. This causes the exhaust steam in the engine cylinder to be drawn into the condenser.

The condensed exhaust steam collects at the bottom of the condenser, is drawn into the air pump cylinder and is discharged while heated to the hot well of the boiler. The use of this hot water as feed water is a considerable saving; but the great advantage of the condenser is the reduction in back pressure.

Hot water cannot be used by an ordinary pump as well as cold water because of the pressure of the vapor which arises from the hot water. In the condenser shown, the water and air pumps are run by the piston in the steam cylinder. Sometimes these pumps are connected to the main engine and receive motion from the shaft or crosshead.

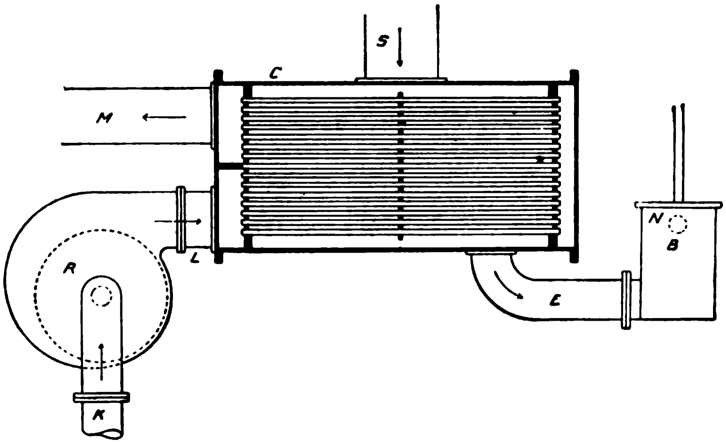



Fig. 27.

The general arrangement of the surface condenser with the necessary pumps is shown in Fig. 27. The cooling water enters through the pipe K, and flows to the circulating pump R, which forces the water into the condenser through the pipe L. In case the water enters the condenser under pressure from city mains no circulating pump is necessary. After flowing through the tubes it leaves the condenser by means of the exit M, and flows away. Exhaust steam enters at S, and is condensed by coming in contact with the cold tubes; the water (condensed steam) then falls to the bottom of the condenser and flows to the air pump B by the pipe E. The air pump removes the air, vapor and condensed steam from the condenser and forces it through the pipe N into the hot well, from which it goes to the boilers or to the feed tank

The circulating pump, when separate from the condenser, is usually of the centrifugal type. This pump consists of a fan or wheel which is made up of a central web or hub, and arms or vanes. This pump is shown in Fig. 28. The vanes are curved, and as the water is drawn in at the central part the vanes throw it off at the circumference. A suitable casing directs the flow. This type of pump is advantageous because there are no valves to get out of order, and as the lift is little, if any, the pump will discharge a large volume of water in a nearly constant stream. The circulating pump is usually so placed that the water flows to it under a slight head. The pump is driven by an independent engine so that the circulating water may cool the condenser even if the main engine is not working.

The centrifugal pump works more smoothly and with less trouble than an ordinary force pump, because it is not reciprocating and it has no valves.

Fig. 28.

*Jet Condensers.* Fig. 29 shows the longitudinal section of an independent jet condenser with the pump. The cold water used to condense the steam enters at A, passes down the spray pipe B, and is broken into a fine spray by means of the spray cone C. This action insures a rapid and thorough mixing of the steam and water and consequently a rapid condensation. The exhaust steam enters at D, with a comparatively high velocity, which is imparted to the water. The whole mixture of water, steam and vapor passes at high velocity through the conical chamber E to the pump cylinder F. The pump forces this water to the pipe G. The spray cone is adjusted by the stem which passes through the stuffing box at the top of the condenser. The valves are shown at H and K. The steam end of the pump is at L. Motion of the valve is produced by the rocker arm J.

In Fig. 30 a jet condenser is shown connected to a stationary engine and boiler. The exhaust pipe leads from the engine to the condenser, the arrows indicating the direction of flow. Cold water enters the condenser through a pipe connected to the well. Part of the mixture of exhaust steam and condensed water goes to the feed-water heater, which is kept nearly full; the rest passes to the sewer. The heater is placed a little above the feed pump, so that the water will enter the pump under a slight head, because the pump cannot raise water warmed by exhaust steam as readily as cold water.

The surface condenser is used almost universally in marine practice. Its first cost is more than that of the jet condenser and it requires more condensing water, but it allows only the condensed steam to return to the boiler. It is also used in stationary work when the condensing water is very impure. The jet condenser is not adapted for marine work, as it pumps both the condensing water and the condensed steam to the hot well. Hence, if salt water or water containing lime is used, it will enter the boiler and form sediment and scale. This type is used

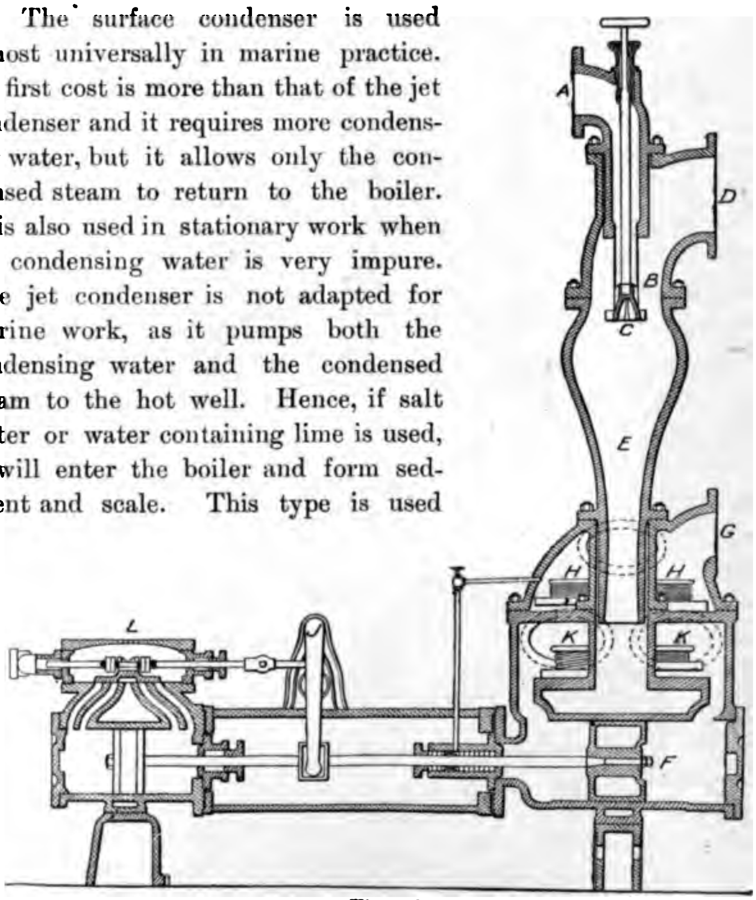


Fig. 29.

where fresh and moderately pure water is available.

It has been mentioned before that Watt always condensed the exhaust steam from his engines, and that when higher pres-

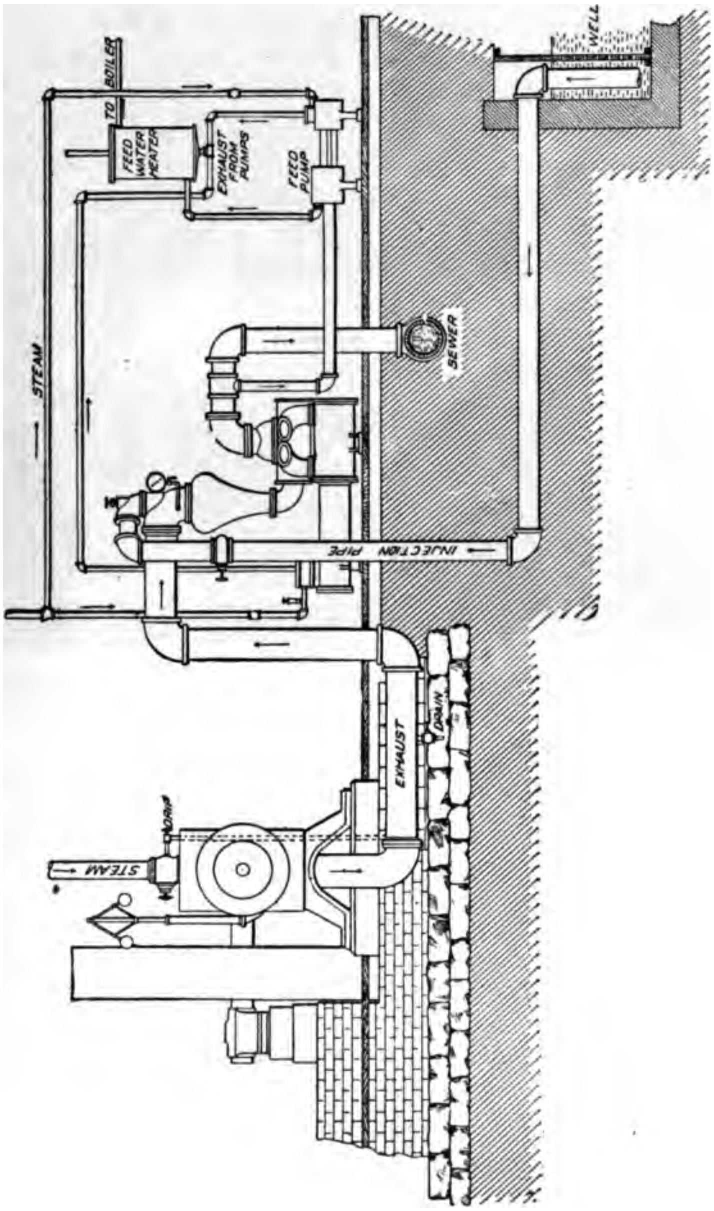

STEAM
TO BOILER
FEED WATER HEATER
EXHAUST FROM PUMPS
FEED PUMP
SEWER
INJECTION PIPE
EXHAUST
DRAIN
WELL
STEAM
DRIP

Fig. 30.

sures came into use some makers let the steam discharge into the atmosphere. This leads to the distinction between condensing and noncondensing engines. Both types are in common use, but the condensing engines are much more economical than the non-condensing, as far as fuel is concerned; but to condense the steam, considerable water is necessary, and condensing engines cost more and require more care. Consequently in some cases it is quite as economical, all things considered, to use the noncondensing engine.

## COOLING TOWERS.

It sometimes happens that it is impossible to place a steam plant in close proximity to a natural water supply. In such cases the water necessary for the condenser (the circulating water) is expensive, and if the cost is very great it does not pay to add the condenser, because the cost of the circulating water might more than offset the gain from condensing. If, however, some means could be provided whereby the circulating water as it issues from the condenser could be cooled and then used over again in the condenser, the noncondensing engine could then be run condensing; thus taking advantage of all the benefits due to the use of reduced back pressure and heating of the feed water. This has been attempted by conducting the heated discharge water to a pond, where it is allowed to cool to a lower temperature before being used again. Another plan is to place in the yard or on the roof of the building large shallow pans, in which the water is cooled by being exposed to the atmosphere. These methods are unsatisfactory on account of the considerable area necessary and the slow action. In addition they are uncertain, because they are dependent upon atmospheric conditions.

A more efficient and at the same time more expensive process is to use a cooling tower or a water table. Fig. 31 shows the general arrangement of a cooling tower located upon the roof of a building. The discharge from the condenser is led, as shown by the arrows, to the top of the cooling tower, where it is cooled before being returned to the condenser. This cooling is effected by distributing the water, by a system of piping, to the upper edge of a series of mats or slats, over the surface of which the water

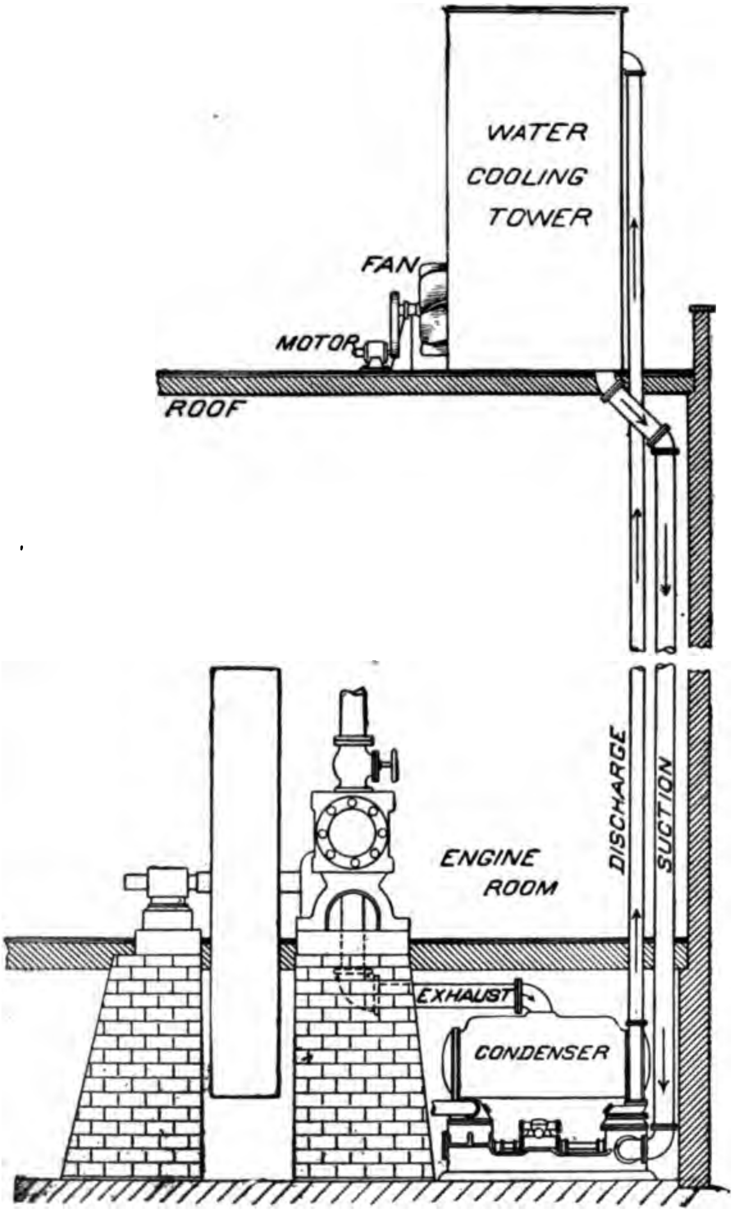

WATER
COOLING
TOWER
FAN
MOTOR
ROOF
DISCHARGE
SUCTION
ENGINE
ROOM
EXHAUST
CONDENSER

Fig. 31.

flows in a thin film to a reservoir which is situated in the bottom of the cooling tower. The mats partially interrupt the flow, and by breaking up the water in small streams cause new portions to be exposed to the cooling effect of the air currents. The water from the reservoir then flows downward through the suction pipe, and is pumped by the circulating pump through the condenser. After passing through the condenser and absorbing heat from the exhaust steam, it rises through the discharge pipe and commences the circuit over again.

The tower may have several arrangements and be made of various materials. A satisfactory form is constructed of steel plates; within the tower are a large number of mats of steel wire cloth galvanized after weaving.

To assist in the cooling of the water, the air is often made to circulate rapidly by means of a fan, which forces the air into the lower part of the tower and upwards among the mats. This fan is usually of the ordinary type, and may be driven by an electric motor, a line of shafting, or by a small independent engine.

In case the fan is not used, the mats are arranged so that they are exposed to the atmosphere, as shown in Fig. 32. This of course necessitates the removal of the steel casing. Usually the fanless tower must be placed at the top of a high building, or in some position where the currents of air can readily circulate among the mats.

With an efficient type of cooling tower the water may be reduced from 30 to 50°, thus allowing a vacuum of from 22 to 26 inches. This will of course greatly increase the economy of the plant, and allow the heated feed water to be returned to the boiler.

The water table is usually made of wooden slats placed in the ground near the plant. After trickling over the slats and becoming cooled by the air, it collects in the bottom of the reservoir and is then pumped into the condenser.

## THE FLY WHEEL.

It is evident that while the piston can push the crank around during part of the stroke, and pull it during another part, there are still two places (called dead points) at the ends of the stroke, where the pressure on the piston, no matter how great, can exert

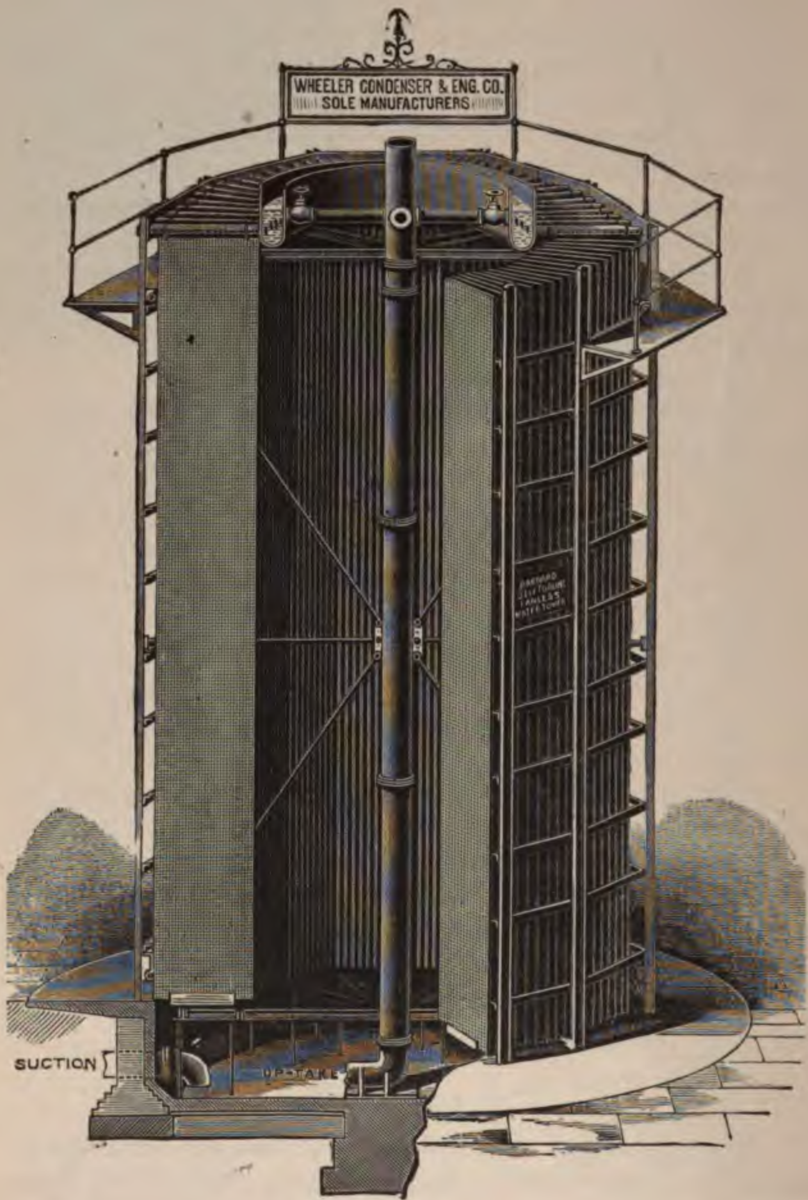

WHEELER CONDENSER & ENG. CO.
SOLE MANUFACTURERS
SUCTION
UPTAKE

Fig. 32.

no turning moment on the shaft. Therefore, if some means is not provided for making the shaft turn past these points without the assistance of the piston, it may stop. This means is provided in the fly wheel, which is merely a heavy wheel placed on the shaft. On account of the momentum of the fly wheel it cannot be stopped quickly, and therefore carries the shaft around until the piston can again either push or pull.

If a long period be considered, the mean effort and the mean resistance must be equal; but during this period there are temporary changes of effort, the excesses causing increase of speed. To moderate these fluctuations several methods are employed.

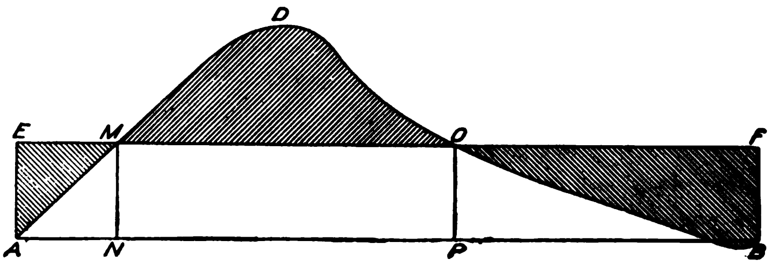



Fig. 33.

The turning moment on the shaft of a single cylinder engine varies, first, because of the change in steam pressure, and second, on account of the angularity of the connecting rod. Before the piston reaches mid-stroke the turning moment is a maximum, as shown by the curve, (Fig. 33). While near the ends of the stroke (the dead points) the turning moment diminishes and finally becomes zero. This, of course, tends to cause a corresponding change in the speed of rotation of the shaft. In order to have this speed as nearly constant as possible, and to give a greater uniformity of driving power, the engine may be run at high speed. By this means the inertia of the revolving parts, such as the connecting rod and crank, causes less variation. When the work to be done is steady and always in the same direction (as in most factories), a heavy fly wheel may be used.

The heavier the fly wheel, the steadier will be the motion. It is, of course, desirable in all factory engines to have steady motion, but in some it is more important than in others. For instance, in a cotton mill it is absolutely necessary that the machinery shall move with almost perfect steadiness; consequently mill engines always have very large, heavy fly wheels. It is undesirable to use larger wheels than are absolutely necessary, because of the cost of the metal, the weight on the bearings and the danger from bursting.

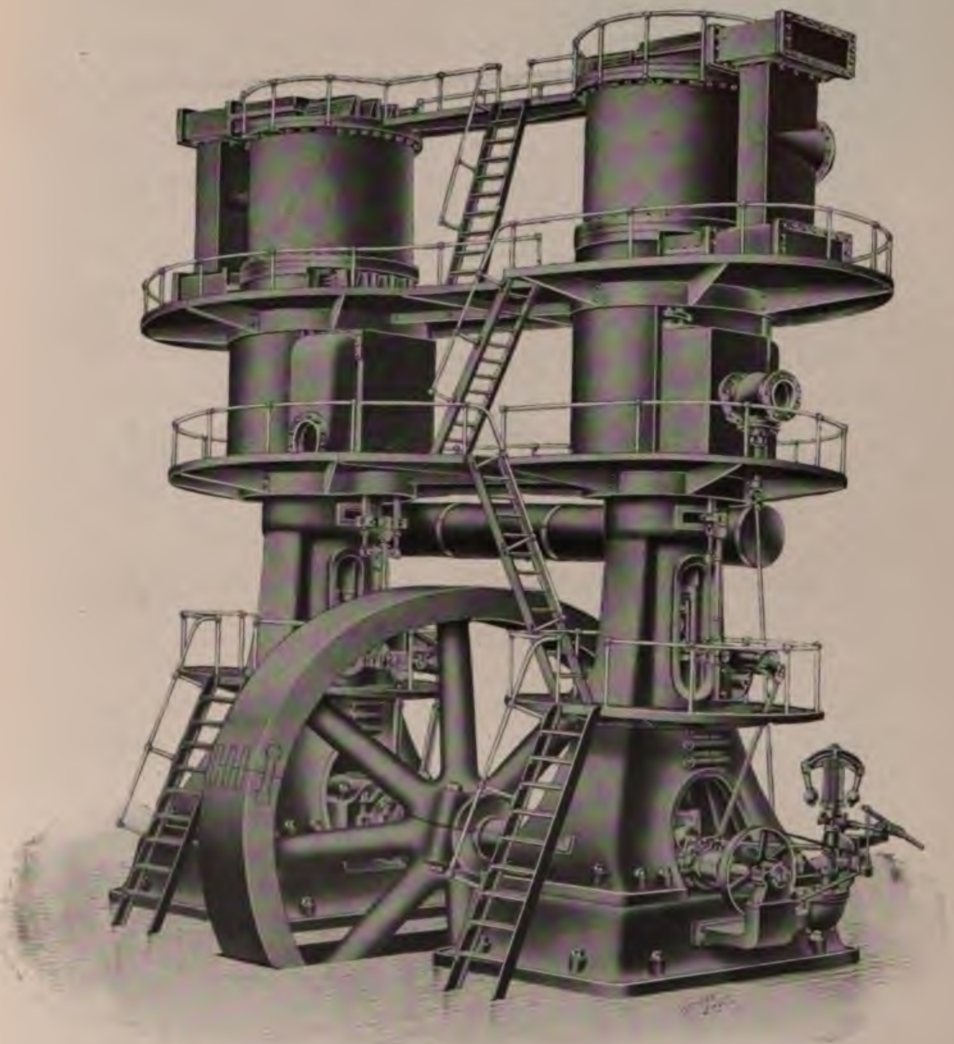
If the turning moment which is exerted on the shaft from the piston could be made more regular, and if dead points could be avoided, it would be possible to get a steadier motion with a much smaller fly wheel.

If the engine must be stopped and reversed frequently, it is better to use two or more cylinders connected to the same shaft. The cranks are placed at such angles that when one is exerting its minimum rotative effort, the other is exerting its maximum turning moment; or, when one is at a dead center, the other is exerting its greatest power. These two cylinders may be identically the same, as is the case with most hoisting engines and with many locomotives; or the engine may be compound or triple expansion.

This arrangement is also used on engines, for mines, collieries, and for hoisting of any sort where ease of stopping, starting and reversing are necessary. Simple expansion engines with their cranks at right angles are said to be coupled.

The governor adjusts the power of the engine to any large variation of the resistance. The fly wheel has a duty to perform which is similar to that of the governor. It is designed to adjust the effort of the engine to sudden changes of the load which may occur during a single stroke. It also equalizes the variation in rotative effort on the crank pin. The fly wheel absorbs energy while the turning moment is in excess of the resistance and restores it while the crank is at or near the dead points. During these periods the resistance is in excess of the power.

The action of the fly wheel may be represented as in Figs. 33 and 34. It will be noticed that in Fig. 33 the curve of crank effort runs below the axis toward the end of the stroke. This is because the compression is greater than the pressure near the end of expansion, and produces a resultant pressure on the piston. In Fig. 34 the effect of compression has been neglected. Let us suppose that the resistance, or load, is uniform. In Fig. 33 the line



VERTICAL CROSS COMPOUND BLOWING ENGINE.
Buckeye Engine Company.

A B is the length of the semi-circumference of the crank pin, or it is the distance the crank pin moves during one stroke. The curve A M D O B is the curve of turning moment for one stroke. M N is the mean ordinate, and therefore A E F B represents the constant resistance. The effort and resistance must be equal if the speed is uniform; hence A E F B = A M D O B. Then area A E M + area O F B = area M D O. At A the rotative effort is zero because the crank pin is at the dead point; from A to N the turning moment is less than the resistance. At N the resistance and the effort are equal. From N to P the effort is in excess of the resistance. At P the effort and resistance are again equal. From P to B the resistance is greater than the effort. In other words, from A to N the work done by the steam is less than the resist-

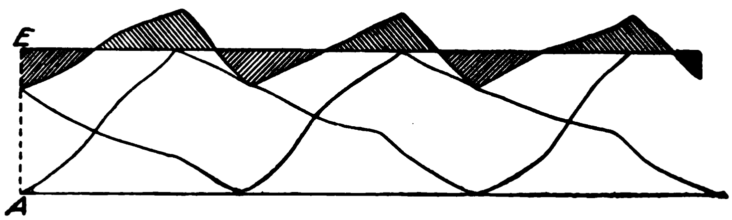



Fig. 34.

ance. This shows that the work represented by the area A E M must have been done by the moving parts of the engine. From N to P the work done by the steam is greater than the resistance, and the excess of energy is absorbed by or stored in the moving parts. From P to the end of the stroke, the work represented by the area O F B is done on the crank pin by the moving parts.

We know from the formula, $E = \frac{W V^2}{2g}$, that energy is proportional to the square of the velocity. Hence as W and $g$ remain the same, the velocity must be reduced when the moving parts are giving out energy, and increased when receiving energy. Thus we see that the tendency of the crank pin is to move slowly, then more rapidly. The revolving parts of an engine have not sufficient weight to store this surplus energy, hence a heavy fly wheel is used.

In case there are two engines at right angles, two effort curves must be drawn, as shown in Fig. 34. The mean ordinate A E is equal to the mean or constant resistance. There are two minimum and two maximum velocities in one stroke. The diagram shows that the variation is much less than for a single cylinder; hence a lighter fly wheel may be used.

The *weight of the fly wheel* depends upon the character of the work done by the engine. For pumping engines and ordinary machine work the effort need not be as constant as for electric lighting and fine work. In determining the weight of a fly wheel the diameter of the wheel must be known, or the ratio of the diameter of the wheel to the length of stroke. If the wheel is too large, the high linear velocity of the rim will cause too great a centrifugal force and the wheel is likely to break. In practice, about 6,000 feet per minute is taken as the maximum linear velocity of cast-iron wheels. When made of wood and carefully put together, the velocity may be taken as 7,000 to 7,500 feet per minute.

We know that linear velocity is expressed in feet per minute by the formula, $V = 2\pi R N$, or $V = \pi D N$.

Then if a wheel runs at 100 revolutions per minute, the allowable diameter would be,

$$6{,}000 = 3.1416 \times D \times 100$$

$$D = \frac{6{,}000}{3.1416 \times 100} = 19.1 \text{ feet.}$$

If a wheel is 12 feet in diameter the allowable speed is found to be,

$$N = \frac{V}{\pi D}$$

$$= \frac{6{,}000}{3.1416 \times 12} = 159 \text{ revolutions per minute.}$$

It is usual to make the diameter a little less than the calculated diameter.

Having determined the diameter, the weight may be calculated by several methods. There are many formulas to obtain this result given by various authorities. One formula is given as follows:

$$W = \frac{C \times d^2 \times b}{D^2 \times N^2}$$

In the above, W = weight of the rim in pounds
$d$ = diameter of the cylinder in inches
$l$ = length of stroke in inches
D = diameter of fly wheel in feet
N = number of revolutions per minute

C is a constant which varies for different types and conditions.

| | |
|---|---|
| Slide-valve engines, ordinary work, | C = 350,000 |
| Corliss engines, ordinary work, | C = 700,000 |
| Slide-valve engines, electric lighting, | C = 700,000 |
| Corliss engines, electric lighting, | C = 1,000,000 |
| Automatic high-speed engines, | C = 1,000,000 |

Example. Let us find the weight of a fly-wheel rim for an automatic high-speed engine used for electric lighting. The cylinder is 24 inches in diameter; the stroke is 2 feet. It runs at 300 revolutions per minute, and the fly wheel is to be 6 feet in diameter.

$$W = 1,000,000 \times \frac{(24)^2 \times 24}{36 \times 90,000}$$

$$W = 4,266 \text{ pounds}$$

Another example. A plain slide-valve engine for electric lighting is 20″ × 24″. It runs at 150 revolutions per minute. The fly wheel is to be 8 feet in diameter. What is the weight of its rim?

$$W = 700,000 \times \frac{400 \times 24}{64 \times 22,500}$$

$$W = 4,666 \text{ pounds.}$$

The weight of a fly wheel is considered as being in the rim. The weight of the hub and arms is simply extra weight. Then, if we know the weight of the rim and its diameter, we can find the width of face and thickness of rim. Let us assume the given diameter to be the mean of the diameter of the inside and outside of the rim.

Let $b$ = width of face in inches
$t$ = thickness of rim in inches
$d$ = diameter of fly wheel in inches
.2607 = weight of 1 cubic inch of cast iron

Then,

$$W = .2607 \times b \times t \times \pi d$$
$$= b \times t \times .819\, d$$

Suppose the rim of a fly wheel weighs 6,000 pounds, is 9 feet in diameter, and the width of the face is 24 inches. What is the thickness of the rim?

$$t = \frac{W}{.819\, d\, b}$$

$$= \frac{6{,}000}{.819 \times 108 \times 24}$$

$$= 2.83 \text{ inches}$$

In this case the rim would probably be made $2\frac{13}{16}$ inches thick. The total weight, including hub and arms, would probably be about 8,000 pounds.

## GOVERNORS.

The load on an engine is never constant, although there are cases where it is nearly uniform. While the engine is running at constant speed, the resistance at the fly-wheel rim is equal to the work done by the steam. If the load on the engine is wholly or partially removed, and the supply of steam continues undiminished, the force exerted by the steam will be in excess of the resistance. Work is equal to force multiplied by distance; hence, with constant effort, if the resistance is diminished, the distance must be increased. In other words, the speed of the engine will be increased. The engine will "race," as it is called. Also, if the load increases and the steam supply remains constant, the engine will "slow down."

It is evident, then, that if the speed is to be kept constant some means must be provided so that the steam supply shall at all times be exactly proportional to the load. This is accomplished by means of a governor.

Steam-engine governors act in one of two ways: they may regulate the *pressure* of steam admitted to the steam chest, or they may adjust the speed by altering the *amount* of steam admitted. Those which act in the first way are called throttling governors, because they throttle the steam in the main steam pipe. Those of the latter class are called automatic cut-off governors, since they automatically regulate the *cut-off*.

Theoretically, the method of governing by throttling the steam causes a loss in efficiency, but the throttling superheats the steam, thus reducing cylinder condensation. By the second method the loss in efficiency is very slight, unless the ratio of expansion is already great, in which case shortening the cut-off causes more cylinder condensation. This subject will be taken up in detail later.

In most governors, centrifugal force, counteracted by some other force, is employed. A pair of heavy masses (usually iron balls or weights) are made to revolve about a spindle, which is driven by the engine. When the speed increases, centrifugal force increases, and the balls tend to fly outward; that is, they revolve in a larger circle. The controlling force, which is usually gravity or springs, is no longer able to keep the balls in their former path. When, therefore, the increase is sufficiently great, the balls in moving outward act on the regulator, which may throttle the steam or cause cut-off to occur earlier.

With the throttling governor a balanced throttle valve is placed in the main steam pipe leading to the valve chest. If the engine runs faster than the desired speed, the balls are forced to revolve at a higher speed. The increase in centrifugal force will cause them to revolve in a larger circle and in a *higher plane.* By means of some mechanism (levers and gears) the spindle may be forced downward, thus partially closing the valve. The engine, therefore, takes steam at a lower pressure, and the power supplied being less, the speed falls slightly.

Similarly, if the load is increased, the engine slows down, which causes the balls to drop and open the valve more widely; steam at higher pressure is then admitted, and the speed is increased to the regular number of revolutions.

With the Corliss or Wheelock engine the governor of this type acts differently. Instead of throttling the steam in the steam pipe, the governor is connected to the releasing gear by rods. An increase of speed causes the releasing gear to unhook the disengaging link earlier in the stroke. This causes earlier cut-off, which of course decreases the power and the speed, since the amount of steam admitted is less. If for any reason the load increases, the governor causes the valves to be held open longer. The cut-off, therefore, occurs later in the stroke.

One of the most common forms of governor is similar to that invented by James Watt. It is called, from its appearance, the pendulum governor. It is shown in Fig. 35. To consider the theory of the pendulum governor, the masses of the balls are assumed to be concentrated at their centers, and the rods made of some material having no weight.

When the governor is revolving about its axis at a constant speed the balls revolve in a circle having a radius $r$ The distance from this plane to the intersection of the rods, or the rods produced, is called the height and is equal to $h$.

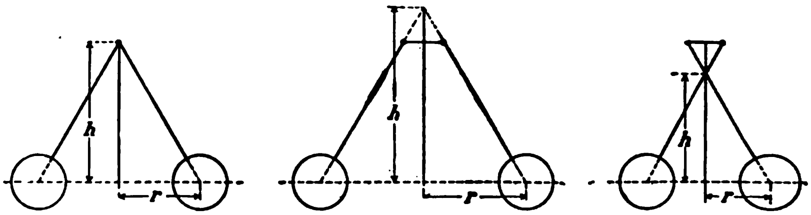


Fig. 35.

If the balls revolve faster, the centrifugal force increases, $r$ becomes greater and $h$ diminishes. We know that centrifugal force is expressed by the formula,

$$F = \frac{Wv^2}{g\,r}$$

Then centrifugal force varies inversely as the radius.

While the pendulum is revolving, centrifugal force acts horizontally outward and tends to make the balls fly from the center; gravity tends to make the balls drop downward. In order that the balls shall revolve at a certain height, the moments of these two forces about the center must be equal, or the weight of the balls multiplied by their distance from the center must equal the centrifugal force multiplied by the height, or.

$$W \times r = F \times h$$

from which,

$$\frac{h}{r} = \frac{W}{F}$$

or,

$$\frac{h}{r} = \frac{W}{\frac{Wv^2}{g\,r}} = \frac{g\,r}{v^2}$$

from which,

$$h = \frac{g\,r^2}{v^2}$$

Now we know that the linear velocity of a point revolving in the circumference of a circle is expressed as $2 \pi r N$ feet per second.

Then, $$h = \frac{g r^2}{v^2} = \frac{g r^2}{4\pi^2 r^2 N^2} = \frac{g}{4\pi^2 N^2}$$

Since we know the values of $g$ and $\pi$ we can write the formula,

$$h = \frac{32.16}{4 \times 3.1416^2 \times N^2} = \frac{.8146}{N^2} \text{ feet, or}$$

$$h = \frac{9.775}{N^2} \text{ inches}$$

If N is the number of revolutions per minute,

$$h = \frac{2,932.56}{N^2} \text{ feet}$$

$$h = \frac{35,190.7}{N^2} \text{ inches}$$

From the above formula, we see that the height is independent of the weight of the balls or the length of the rod; it depends upon the number of revolutions. The height varies inversely as the square of the number of revolutions.

The ordinary pendulum governor is not isochronous; that is, it does not revolve at a uniform speed in all positions; the speed changes as the angle between the arms and the spindle changes.

The early form consisted of two heavy balls suspended by links from a pin connection in a vertical spindle, as shown in Figs. 36 and 37. The spindle is caused to revolve by belting or gearing from the main shaft, so that as the speed increases, centrifugal force causes the balls to revolve in a circle of larger and larger diameter. The change of position of these balls can be made to affect the controlling valves so that the admission or the throttling shall vary with their position. With this governor it is evident that for a given speed of the engine there is but one position possible for the governor; consequently one amount of throttling or one point of cut-off, as the case may be. If the load varies, the speed of the engine will change. This causes the position of the governor balls to be changed slightly, thus altering the pressure

But in order that the pressure or cut-off shall remain changed, the governor balls must stay in their new position. That is to say, the speed of the engine must be slightly changed. Thus with the old ball governors there was a slightly different speed for each load. This condition has been greatly improved by various modifications until now such governors give excellent regulation.

While the engine is running with a light load, the valve controlled by the governor will be open just enough to admit steam at a pressure that will keep the engine running at a given speed. Now, if the engine is heavily loaded, the throttle valve must be wide open. The change of opening is obtained by a variation in the height of the governor, which is caused by a change of speed. Thus we see that the governor can control the speed only within certain limits which are not far apart. The difference in the extreme heights of the governor must be sufficient to open the throttle its entire range. In most well-designed engines the speed will not vary more than 4 per cent; that is, 2 per cent above or below the mean speed.

From the formula $h = \frac{35{,}190.7}{N^2}$, we can compute the heights corresponding to given speeds as shown by the following table:

| Number of Revolutions per Minute. | Height in Inches. | Variation of Height in Inches .2 per cent. |
|---|---|---|
| 250 | .563 | .0225 |
| 200 | .879 | .035 |
| 175 | 1.149 | .046 |
| 150 | 1.564 | .062 |
| 125 | 2.252 | .090 |
| 100 | 3.519 | .140 |
| 75 | 6.256 | .250 |
| 50 | 14.076 | .563 |

In the above table the second column is found from the formula $h = \frac{35{,}190.7}{N^2}$. The third column is the variation in height for a speed variation of 4 per cent or 2 per cent either above or below the mean.

From the table we see that for a considerable variation of speed there is but slight variation in the height of the governor. Also for high speeds the height of the governor is so small that it would be difficult to construct it. The slight variation in height is too small to control the cut-off or throttling mechanism throughout the entire range.

Other disadvantages of the fly-ball governor are as follows: it is apparent that the valves must be controlled by the weight of the governor balls. In large engines this requires very heavy balls in order to quickly overcome the resistance of the valves. But these large balls have considerable inertia and will therefore be reluctant to change their speed with that of the engine. The

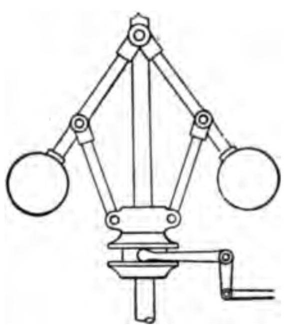


Fig. 36.

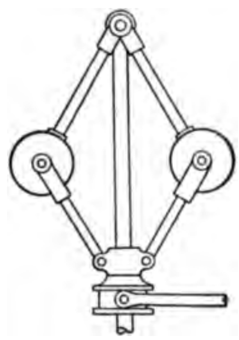


Fig. 37.

increased weight will also increase the friction in the governor joints, and the cramping action existing when the balls are driven by the spindle will increase this friction still further. All these things tend to delay the action of the governor, so that in all large engines the old-fashioned governor became sluggish. The balls had to turn slowly because they were so heavy; this was especially troublesome in high-speed engines.

To remedy these defects the weighted or Porter governor was designed. (See Fig. 38.) It has a greater height for a given speed, and the variation in height for a given variation of speed is greater. When a governor has this latter quality, that is, a great variation in height for a given variation of speed, it is said to be sensitive. By increasing this variation in height the sensitiveness is increased. Thus, if a governor running at 50 revolutions has a variation in height of .57 inch, it is not as sensitive as one having a variation of 1 inch for the same speed.

In the weighted governor, the weight is formed so that the center of gravity is in the axis. It is placed on the spindle and is free to revolve. The weight adds to the weight of the balls, and thus increases the moment of the weight. It does not, however, add to the centrifugal force, and hence the moment of this force is unchanged. We may then say the weight adds effect to the weight but not to the centrifugal force, and as a consequence the height of the governor, for a given speed, is increased. If we let W equal the combined weight of the balls as before, and W′ equal the added weight, the moments are,

$$(W + W') \times r = F\,h$$

$$(W + W') \times r = \frac{W\,v^2}{g\,r} \times h$$

$$h = (W + W')\,r \times \frac{g\,r}{W\,v^2}$$

$$= \frac{(W + W')\,r^2\,g}{W \times 4\,\pi^2\,r^2\,N^2}$$

$$= \frac{(W \times W')}{W} \times \frac{g}{4\,\pi^2\,N^2}$$

We know that $\frac{g}{4\,\pi^2\,N^2} = \frac{.8146}{N^2}$.

Then $h = \left\{ \frac{W + W'}{W} \right\} \times \frac{.8146}{N^2}$.

Hence the height of a weighted governor is equal to the height of a simple pendulum governor multiplied by

$$\left\{ \frac{W + W'}{W} \right\} \text{ or } \left\{ 1 + \frac{W'}{W} \right\}.$$

For instance, if the height of a simple pendulum is 10 inches, and the weight of the balls equal to the added weight, the height will be,

$$h = \left\{ \frac{1 + 1}{1} \right\} \times \frac{.8146}{N^2}$$

$$= 2 \times \frac{.8146}{N^2}$$

Thus we see that if a weight equal to the combined weight of the balls is added, the height of the governor will be doubled.

We know that if the balls fall, the cut-off comes later. If the belt driving the governor slips off or breaks, the balls will drop, and, making the cut-off later, will allow the engine to "run away." To diminish this danger many governors are provided with some kind of safety stop, which closes the valve when the governor loses its normal action. Usually a trip is provided which the governor does not touch in its normal positions, but which will be released if the balls drop down below a certain point.

In another arrangement, instead of a weight, a strong spring is used, and this makes it possible to put the governor in any position.

**Spring Governors.** In many cases a spring is used in place of the weight. This type of governor is used frequently on throttling engines; it consists of a pendulum governor with springs added to counteract the centrifugal force of the balls. Thus the height and sensitiveness are increased. Fig. 39 shows the exterior view of a Waters governor, and Fig. 40 the same governor having the safety stop. In this governor the weights are always in the same plane, the variation in height being due to the action of the bell crank levers connecting the balls and spindle. When the balls move outward the spindle moves downward and tends to close the valve. The governor balls revolve by means of a belt and bevel gears. The valve and seat are shown in section in Fig. 41. The valve is a hollow cylinder with three ports, by means of which steam enters the valve. The seat is made in four parts, that is, there are four edges that the steam passes as it enters the valve. The valve being cylindrical and having steam on both sides is balanced, and because of the many openings only a small travel is necessary.

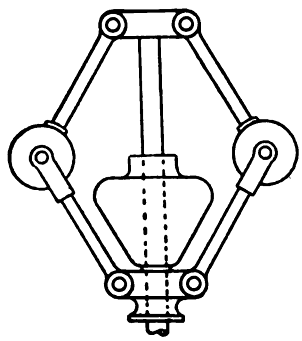


Fig. 38.

**Shaft Governors.** Usually some form of pendulum governor is used for throttling engines. For governing an engine by varying the point of cut-off, shaft governors are generally used; however, Corliss engines and some others use pendulum governors for this purpose. Cut-off governors are called shaft governors because they are placed on the main shaft; they are made in many forms, but the essential features of all are the same. Two pivoted masses or weights are arranged symmetrically on opposite sides of the shaft, and their tendency to fly outward when the speed increases is resisted by springs. The outward motion of the weights closes the admission valve earlier, and the inward motion closes it later. This change is effected by altering the position of the eccentric, either by changing the eccentricity or the angular advance.

Fig. 39.

Fig. 40.

Shaft governors are made in a great variety of ways, no two types being exactly alike. If the principles of a few types are understood, it is easy to understand others. The following illustrates two common methods of shifting the eccentric.

**Buckeye Engine Governor.** The valve of the Buckeye engine is hollow and of the slide valve type. The cut-off valve is inside. The change of cut-off is due to the alteration of the angular advance. The arrangement of the parts which effect the change of angular advance is shown in Fig. 42. A wheel which contains and supports the various parts of the governor is keyed to the shaft. Two arms, having weights A A at the ends, are pivoted to the arms of the wheel at *b b*. The ends having the weights are connected to the collar on the loose eccentric C by means of rods B B.

When the weights move to the position indicated by the dotted lines, the eccentric is turned on the shaft about a quarter of a revolution in the direction in which the engine runs. That is, the eccentric is advanced or the angular advance is increased. Now we know that if the angular advance is increased, cut-off occurs earlier. This is shown by the table on page 12 of "Valve Gears." If the engine had a single plain slide valve the variation of the angular advance would produce too great a variation of lead; but as this engine has a separate valve for cut-off, admission is not altered by the cut-off valve.

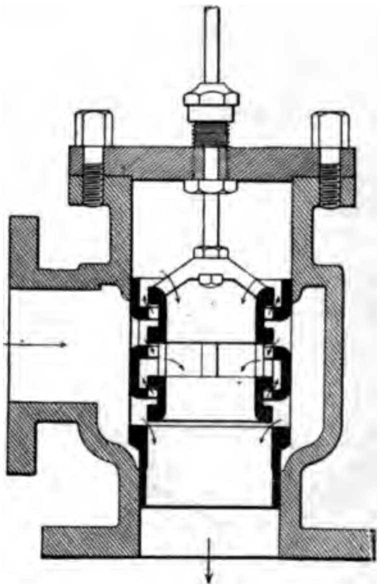


Fig. 41.

The springs F F balance the centrifugal force of the weights. The weights A A are varied to suit the speed; the tension on the springs is altered by means of the screws *c c*. Auxiliary springs are added in order to obtain the exactness of regulation necessary for electric lighting. These springs tend to throw the arms outward, but act only during the inner half of this movement.

**The Straight-Line Engine Governor.** Fig. 43 shows the governor of the straight-line engine. It has but one ball, B, which is linked to the spring S and to the plate D E, on which is the eccentric C. When the ball flies outward in the direction indicated by the arrow F, the eccentric is shifted about the pivot O; the links moving in the direction of arrow H. The ball is heavy and at a considerable distance from the center; hence it has a great centrifugal force, and the spring must be stiff.

The governor of the Buckeye engine alters the cut-off by changing the *angular advance*. The straight-line engine governor changes the *travel* of the valve. Shaft governors which alter the cut-off by changing the valve travel are very common.

## LUBRICATION.

If two pieces of cast iron, just as they come from the foundry, are rubbed together, they will not slide over each other easily, because of little projections. If this same iron is filed or planed,

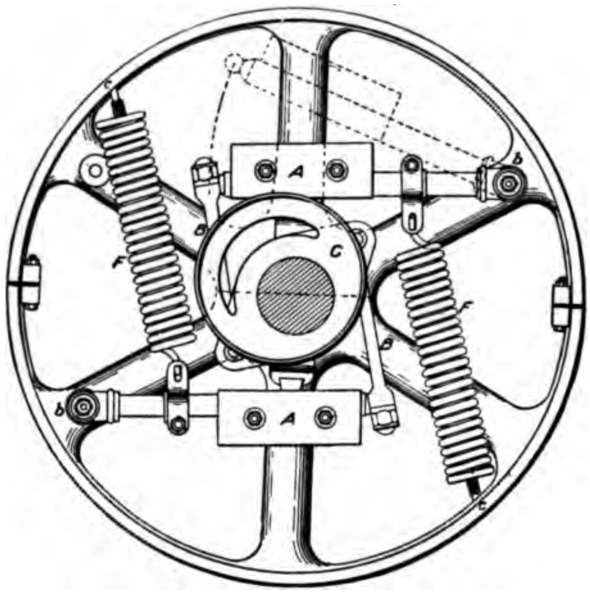



Fig. 42.

the pieces will slide much more easily. This is because the rough places have been smoothed, or filled up with dust. If now we put some engine oil on the pieces, they will slide very easily. This is because the more minute depressions have been filled up and the whole surface is made comparatively smooth. No matter how carefully we might plane and polish any surface, a microscope would show that it was still a little rough.

One cause of loss of power in the steam engine is friction. In all engines there are so many moving parts that it is of great importance that friction should be reduced as much as possible. This is done by making the surfaces in contact smooth and of ample size; also making them of different metals and using oils or other lubricants. The effect of the lubricant is to interpose a thin film between the surfaces. This prevents their coming into actual contact. If the oil is too thin or the pressure too great, the lubricant is squeezed out and the metal surfaces come in contact.

Thus we see that there are certain qualities which a lubricant must have. They are as follows:

The lubricant must be sufficiently fluid, so that it will not itself make the bearing run hard.

It must not be too fluid or it will be squeezed out from between the bearing surfaces. If this happens, the bearing will

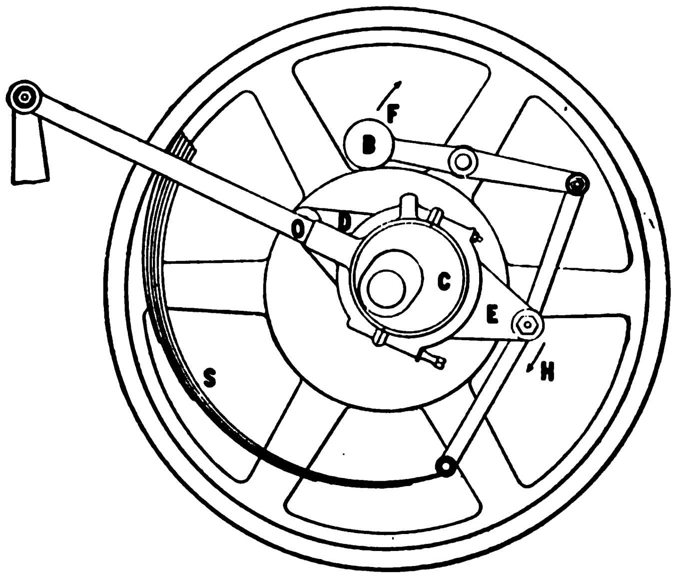



Fig. 43.

immediately begin to heat and cut. The heating will tighten the bearing, and will thus increase the pressure and the cutting.

It must not gum or dry when exposed to the air.

It must not be easily decomposed by the heat generated. If it should be decomposed, it might form substances which would be injurious to the bearings.

It must not take fire easily.

It must contain no acid, and should form no acid in decomposing, as acids corrode the bearings.

Both *mineral* and *animal* oils are used as lubricants. Formerly animal oils were used entirely, but they were likely to decompose at high temperatures and form acids. It is important in using high-pressure steam to have "high-test oils," that is, oils which will not decompose or volatilize at the temperature of the steam. It was the difficulty of getting such oils which made great trouble when superheated steam was first used. Mineral oils will stand these temperatures very readily, and even if they do decompose, they form no acids.

**The Liquid Lubricants**, whether of animal, vegetable or mineral origin, may be used for ordinary bearings, but for valves and pistons heavy mineral oils only are suitable.

**Solid Lubricants.** *Graphite* is used as a lubricant. It is well adapted for heavy pressures when mixed with certain oils. It is especially valuable for heavy pressures and low velocities.

*Metalline* is a solid compound, containing graphite. It is made in the form of solid cylinders, which are fitted to holes drilled into the surface of the bearing. When a bearing is thus fitted no other lubricant is necessary.

*Soapstone* in the form of powder and mixed with oil or fat is sometimes used as a lubricant. Soap mixed with graphite or soapstone is often used where wood is in contact with wood or iron.

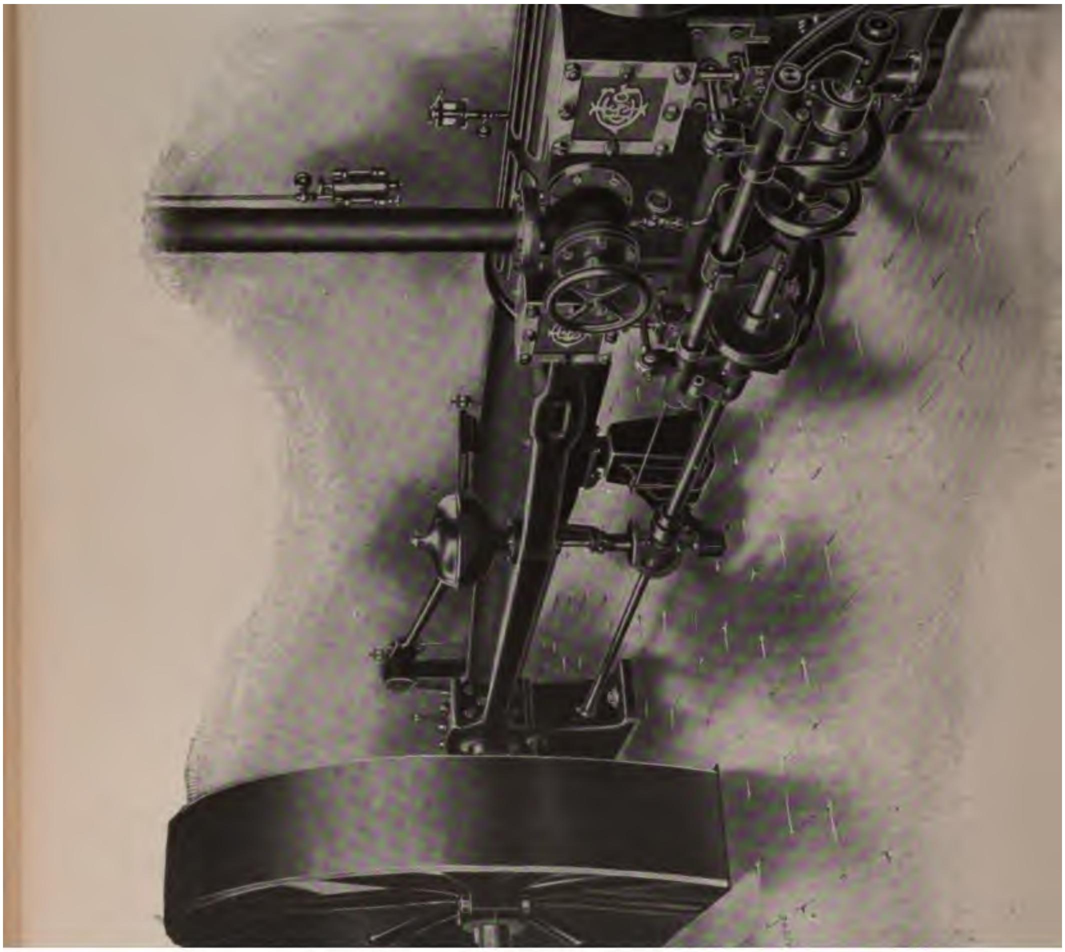
A preparation called *Fiber Graphite* is used for self-lubricating bearings. It is made of finely divided graphite mixed with fibers of wood. It is pressed in molds and afterward fitted to bearings.

For great pressure at slow speed, graphite, lard, tallow and other solid lubricants are suitable. If the pressure is great and the speed high, castor, sperm and heavy mineral oils are used.

For low pressure and high speed, olive, sperm, rape and refined petroleum give satisfaction.

In ordinary machinery, heavy mineral and vegetable oils and lard oil are good. The relative value of various lubricants depends upon the prevailing conditions. Oil that is suitable for one place might not flow freely enough for another.

The quality of oil is of great importance. In many branches



of industry it is imperative that the machinery run as perfectly as possible. On this account and because of the high cost of machinery, only first-class oil should be used. The cylinder oil especially, should be high grade, because the valves, piston and piston rods are the most delicate parts of the engine.

Engines are lubricated by means of oil cups and wipers placed on the bearings wherever required. They are made in many forms, dependent upon the manufacturers. Commonly the oil cup is made with a tube extending up through the oil. A piece of lampwick or worsted leads from the oil in the cup to the tube. Capillary attraction causes the oil to flow continuously and drip down the tube. When not in use, the lampwick should be withdrawn.

The needle oil cup differs from the capillary oil cup in that a small wire or needle extends through the tube and oil; one end rests on the journal to be lubricated. The needle should fit the tube closely, so that when the machinery is at rest no oil will flow. When revolving, the shaft gives the needle a wabbling motion which makes the oil flow. To increase the supply, a smaller needle is used.

The oil cup shown in Fig. 44 is simple and economical. The opening of the valve is regulated by an adjustable stop. The oil may be seen as it flows drop by drop. The cylindrical portion is made of glass, so that the engineer can see how much oil there is in the cup without opening it.

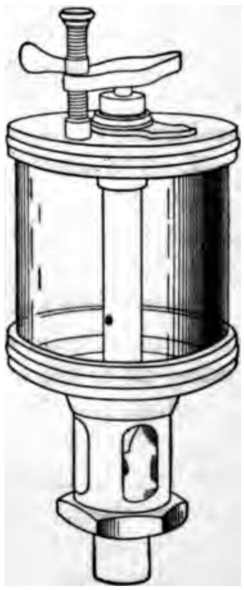


Fig. 44.

A form of wiper crank pin oiler is shown in Fig. 45. The oil cup is attached to a bracket. The oil drops from the cup into a sheet of wicking or wire cloth and is removed at each revolution of the crank pin by means of the cup which is attached to the end of the connecting rod.

Fig. 46 shows a centrifugal oiling device. The oil flows from the oil cup through the tube to the small hole in the crank pin by centrifugal force. It reaches the bearing surface by means of another small hole.

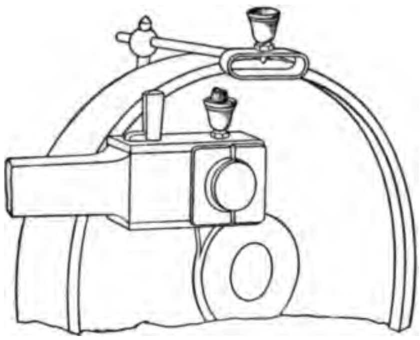


Fig. 45.

In oiling the valve chest and cylinder the lubricant must be introduced against the pressure of the steam. This can be done in several ways, in each of which it is introduced into the steam before it reaches the valve chest and is carried to the surfaces to be lubricated.

The oil can be forced into the steam pipe by a small hand pump or in large engines by an attachment from the engine itself. The supply of oil is, of course, intermittent if the pump is driven by hand, but continuous and economical if driven by the engine.

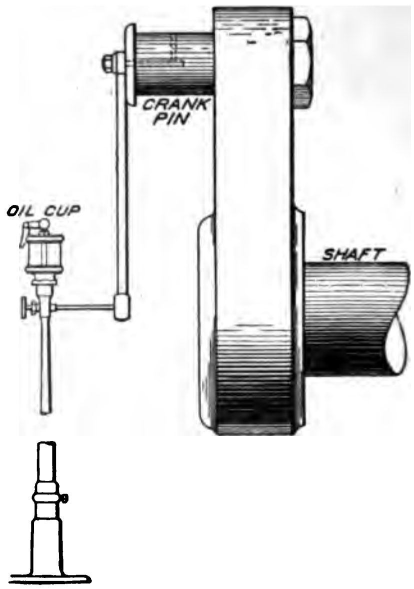



Fig. 46.

**Sight Feed Lubricators.** The most common device for feeding oil to the cylinder is that which introduces the oil drop by drop into the steam when it is in the steam pipe or steam chest. The oil becomes vaporized and lubricates all the internal surfaces of the engine.

Fig. 47 shows the section of a sight feed lubricator. The reservoir O is filled with oil. The pipe B, which connects with the steam pipe, is partly filled with condensed steam, which flows down the small curved pipe E to the bottom of the chamber O. A small portion of the oil is thus displaced and flows from the top of the reservoir O down the tube F, by the regulating valve D, and up through the glass tube S, which is filled with water. It enters the main steam pipe through the connection A. The gage glass G indicates the height of water in the chamber O. To fill the lubricator, close the regulating valve D and the valve in pipe B; the oil chamber can then be drained and filled. If the glass S becomes clogged it may be cleaned by shutting valve D and opening the small valve H. This will allow steam to blow through the glass. After cleaning close valve H and allow glass S to become filled with water before opening the feed valve. The amount of oil fed to the cylinder can be regulated by opening D (Fig. 47) the proper amount. The exact quantity of oil necessary for the engine is not easily determined. For ordinary sizes it is between one drop in two minutes and two drops per minute.

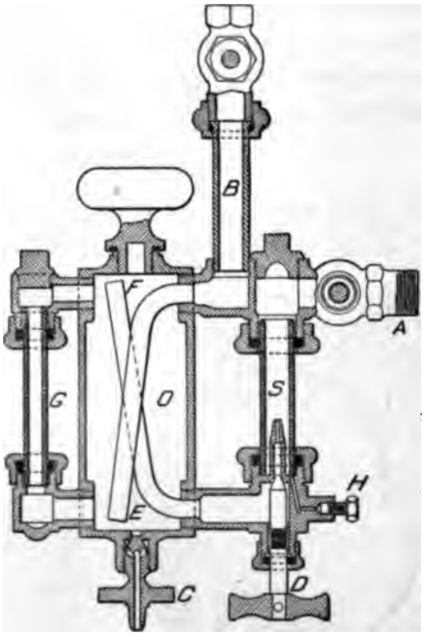


Fig. 47.

Graphite is an excellent lubricant and can be introduced into the cylinder dry or mixed with some heavy grease. It has been used extensively because of the trouble which cylinder oil gives in the exhaust and in the boilers of condensing engines.

In slow-speed engines it is not hard to attend to the oiling; all the parts are moving slowly and can be readily examined and oiled. Many high-speed engines run so fast that it is impossible to examine the various parts, and special means must be provided for lubricating. It is specially important in high-speed engines that there should be no heating. High-speed engines are generally used for electric lighting, and it is absolutely essential that they be kept running at the required speed to avoid flickering lights. Thus, while there is greater liability to heating in high-speed engines, there is also much greater loss in case heating compels the stopping of an engine.

In order to avoid the danger of forgetting to oil a bearing of a high-speed engine, it is customary to have all the bearings oiled from one place. All the oil is supplied to one reservoir and from this reservoir pipes lead to all bearings. If this is not done, large oil cups are supplied, as a rule, so that oiling need not be attended to as frequently.

In some high-speed engines the moving parts are enclosed and the crank runs in a bath of oil. This secures certain oiling and is very effective. All the bearings may be inside this crank case, so that all are oiled in this way. It is impossible for a careless engineer to overlook one point and so endanger the whole engine.

## STEAM TURBINE.

The very earliest records of the steam engine describe a form of steam turbine. It consisted of a hollow sphere, as shown in Fig. 48, mounted on trunnions, through which steam was admitted to the interior. This steam escaped through pipes bent tangentially to the equator line of the sphere. The force of the escaping steam reacted upon the sphere, causing it to revolve on its trunnions. Many centuries later, in 1629, Bianca, an Italian, invented a rotary engine (Fig. 49), in which a jet of steam struck the vanes of a wheel, and thus forced it around in much the same way that a jet of water acts on a Pelton water-wheel. These engines were of little, if any, practical value, and used an immense quantity of steam.

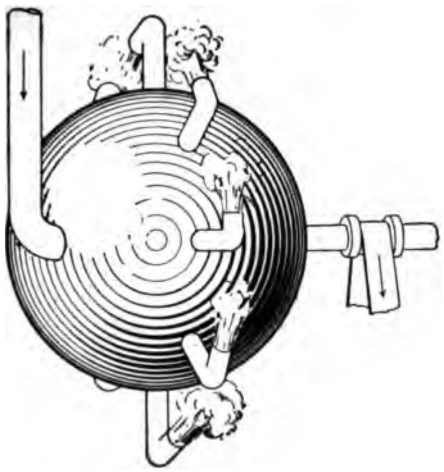


Fig. 48.

In 1705 the reciprocating engine was introduced, and by means of Watt's inventions became so efficient that the development of the rotary engine was out of the question. It will be remembered that Watt introduced the expansive use of steam in the reciprocating engine, which at this time could not be accomplished in the rotary engine, and until within the last few years practically nothing was done to develop the turbine.

Since the days of Watt there has been but one important thermodynamic improvement in the reciprocating engine; namely,

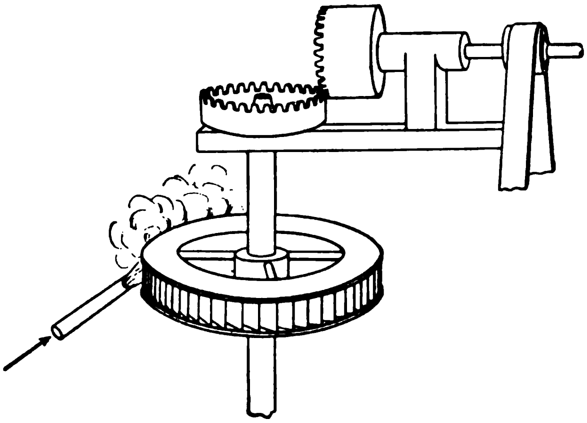


Fig. 49.

the introduction of compound expansion. All other improvements have been in the nature of mechanical devices, and it seems reasonable to suppose that the greatest developments of the future may possibly be in the production of some type other than the reciprocating engine.

In 1883 De Leval invented a successful turbine for running a cream separator, and a short time later Parsons introduced another. Both of these engines employed the expansive force of steam, but each derived this force in a different way.

Since 1883 the development of the turbine has been very rapid. The first engine introduced by De Leval, although far ahead of the earlier forms, was still very wasteful of steam; but now such improvements have been made that their steam consumption compares very favorably with the consumption of good reciprocating engines.

A modern turbine is a tremendously high-speed engine. It does not derive its power from the static force of steam expanding behind a piston, as in the reciprocating engine, but in this case the expanding steam produces kinetic energy of the steam particles. These particles receive a high velocity by virtue of the expansion, and, acting upon the vanes of a wheel, force it around at a high speed of rotation in some such manner as a stream of water rotates a water-wheel.

In the reciprocating engine the expansion produces a force which presses on the piston. In the rotary engine the expansion produces velocity in a jet of steam. This is the fundamental difference between the two forms.

The essential principles of water turbines are equally true of steam turbines. The jet must strike the vanes without a sudden shock, and must leave them in another direction without any sharp deflections. For maximum efficiency the De Leval engine should have a jet velocity equal to one-half the linear velocity of a point on the wheel-rim; for the Parsons these velocities should be equal. If the velocity of steam is 8,000 feet per second, it is easily seen that even one-half of this would cause too great a speed of rotation for safety. It would be difficult to build a wheel that would be strong enough to withstand the centrifugal force at this high speed. It becomes necessary, therefore, to reduce the speed to the limits of safety, and run under a slightly less efficiency.

At such high speed the shaft and wheel should be perfectly balanced, in order that its center of gravity may exactly coincide with the axis of rotation. In practice it has been found impossible to balance the shaft perfectly; and in order that it may revolve about its center of gravity, various means are adopted to overcome the rigidity of an ordinary shaft and bearing. This makes high speed of rotation possible without any apparent vibration.

*De Leval Turbine.* The De Leval turbine shown in Fig. 50 consists of a wheel with suitably shaped buckets, against which a jet of steam is directed. The buckets are on the rim of the wheel and are surrounded by a casing B, which prevents the escape of the steam until it has done its work. A piece of this casing is cut away at A in order to show the buckets. The steam from the nozzle strikes these buckets and is deflected. Thus by the impact of the jet and the reaction due to its deflection, the wheel is caused to revolve at a high speed.

There are usually four nozzles that supply steam to the turbine, one of which is shown in section at D. These nozzles are small at the throat and diverge outward. By making them of the right length and with the proper amount of divergence, the steam can be expanded from the pressure of admission to the

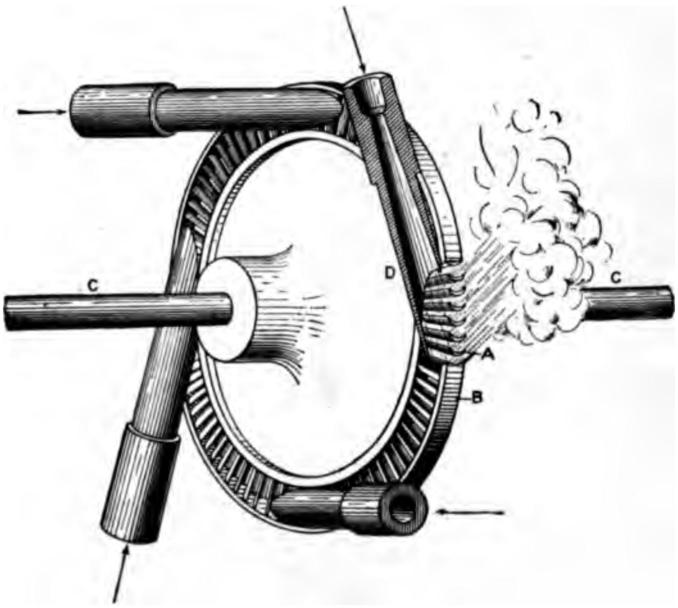



Fig. 50.

pressure of the condenser. Complete expansion is obtained in this diverging nozzle, and the steam leaves it at the exhaust pressure. The steam then works only by virtue of its high velocity.

This turbine has a long, flexible shaft C which can deflect enough to make up for any eccentricity of the center of gravity of the shaft, and thus allow the shaft to revolve about its center of gravity and still have rigid bearings at the end.

Admission is regulated by a throttle-valve, controlled by a fly ball governor.

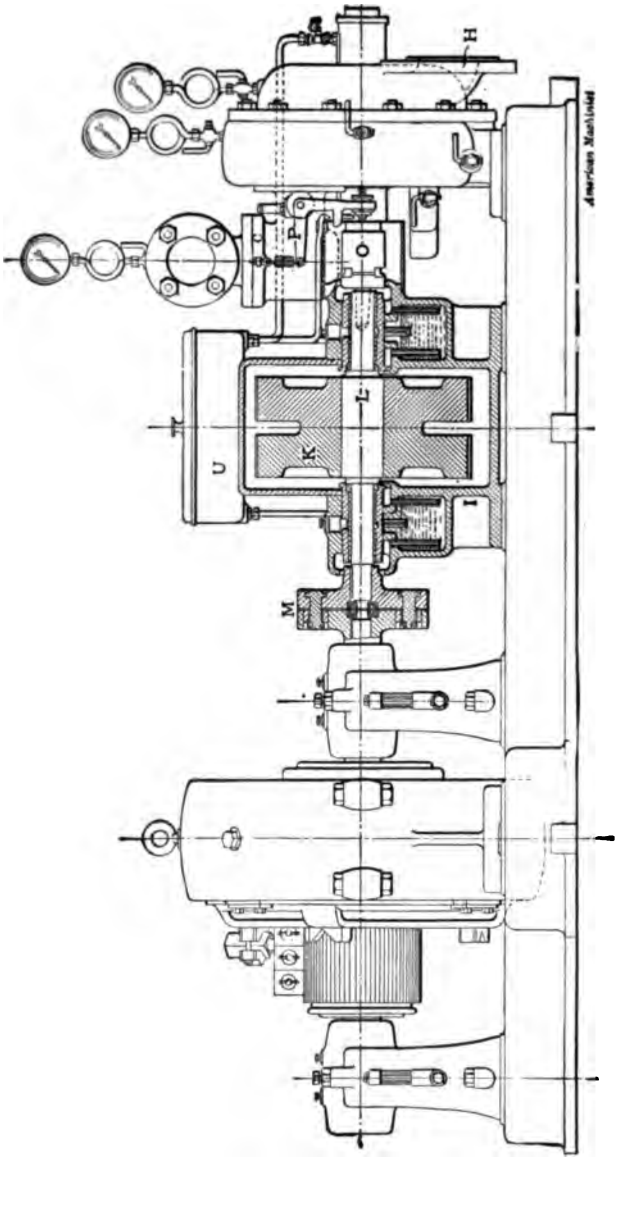



Fig. 51.

Fig. 51 shows a De Leval turbine connected with a generator.

*The Parsons Turbine.* Fig. 52 is a longitudinal section of a Westinghouse-Parsons turbine. Steam enters the chamber A and passes through the turbine vanes to the exhaust chamber B. The vanes are arranged as shown in Fig. 53, and consist of alternate sets, one stationary, the next movable. The steam strikes one and is deflected to the next; thus the action and the reaction occurring in rapid succession cause the movable sets, which are fixed to the shaft, to rotate at a high speed. As the steam passes the different sets of blades, the volume of the passages increases to correspond with the expansion of the steam. In the De Leval the steam was expanded entirely before reaching the wheel, but in the Parsons the expansion is accomplished in the engine itself. As the steam enters the chamber A (see Fig. 52) it presses on the turbine vanes and it also presses equally and in the opposite direction on C, which is really a piston fixed to the shaft. Thus we see that the pressure to the right is equal to the pressure to the left, and there is no end pressure on the bearing of the shaft. $C_1$ and $C_2$ balance the steam pressure in the chambers E and G. At H is a bearing which serves to maintain a correct adjustment of the balance pistons C. There is probably some escape of steam past these balancing pistons, but it is small. The exhaust steam at B presses the turbine toward the left, and would cause an end pressure on the bearing were it not that the pipe K opens a communication between the exhaust chamber B and the back of the balancing pistons, which makes the pressure equal at both ends.

The bearing consists of a gun-metal sleeve surrounded by three concentric tubes. There is a small clearance between these tubes which fills with oil and permits the bearing to run slightly eccentric to counteract any lack of balance in the shaft. Thus the shaft may revolve about its center of gravity, and this oil bearing serves the same purpose as the De Leval flexible shaft.

At P is shown a by-pass valve by means of which live steam may be admitted to the space E, if desirable. Of course this reduces one stage of the expansion, with a corresponding loss of economy, but will increase the power of the turbine. If the condenser fails on a condensing turbine it may still be run at full load by opening the by-pass valve.

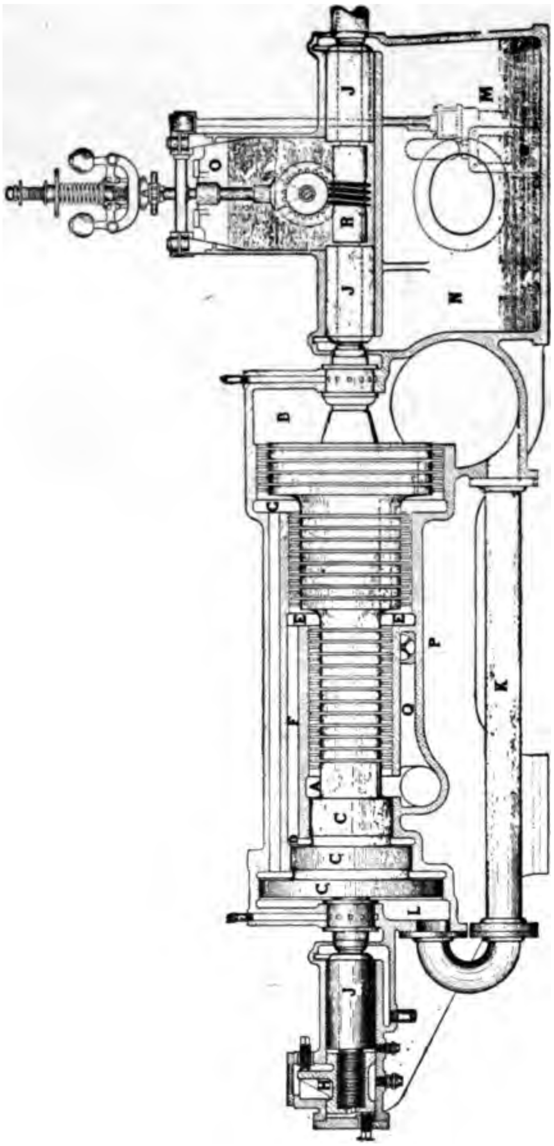



Fig. 52.

Steam is admitted to this turbine in puffs through a reciprocating valve. A fly-ball governor regulates the admission, which is always at boiler pressure.

For electric generators the turbine has many advantages, among them high speed and direct connection. They have small foundations and take up little space; there is slight loss from friction and few parts. Where slow speed is desired a reciprocating engine is probably the best. The turbines use slightly more steam at present than the best reciprocating engines, but the difference between the two types in matter of steam consumption is growing steadily less. The turbine is an efficient engine, but there is doubtless a chance for further improvement.

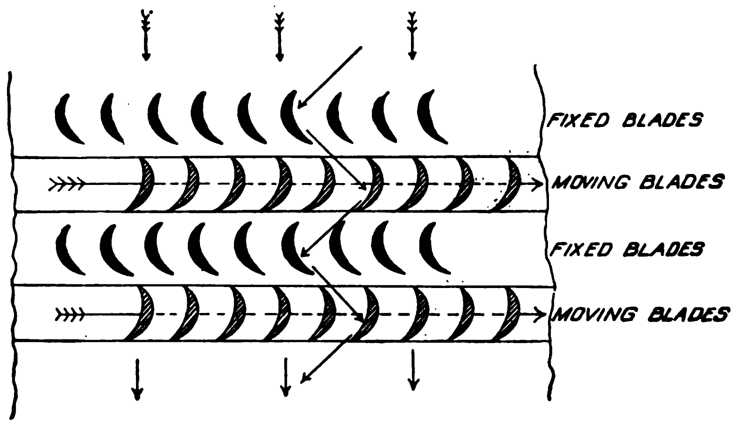
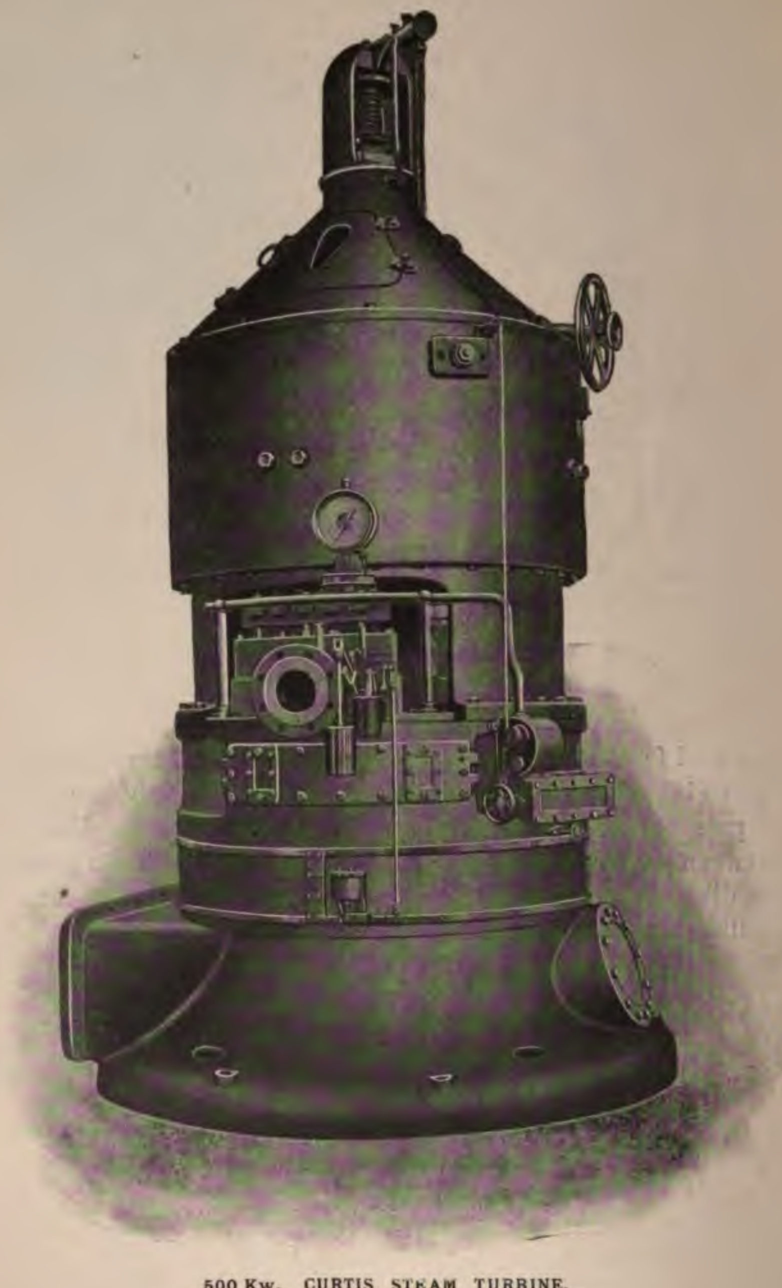



Fig. 53.



**500 Kw. CURTIS STEAM TURBINE.**
Direct Connected to Continuous Current Generator.

## THE CURTIS STEAM TURBINE.

The principle of the Curtis turbine differs from that of any other type in that it permits the use of moderate rotative speeds and very compact and simple mechanism. The turbine is divided into stages, each of which contains one, two, or more, revolving

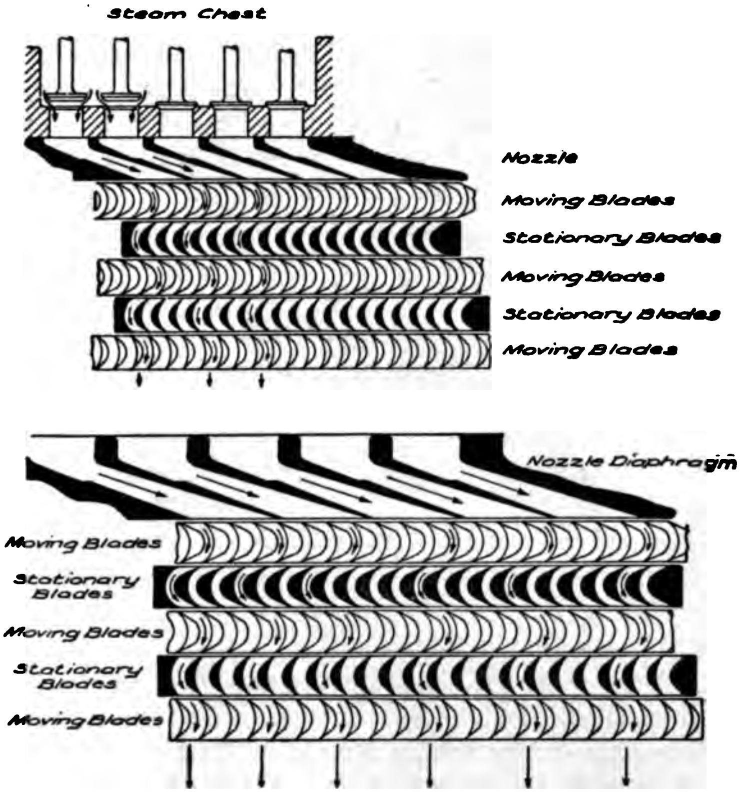



DIAGRAM OF NOZZLES AND BUCKETS IN CURTIS STEAM TURBINE.

buckets supplied with steam from a set of expansion nozzles. As the work is divided into several stages, the nozzle velocity in each stage is reduced, thereby rendering the nozzle action more efficient and perfect than is possible where a higher initial velocity is imparted. The division of pressure between the stages is arranged to utilize the largest possible proportion of the energy of expansion. The position of the moving and stationary buckets with relation to the nozzle is shown in the accompanying diagram.

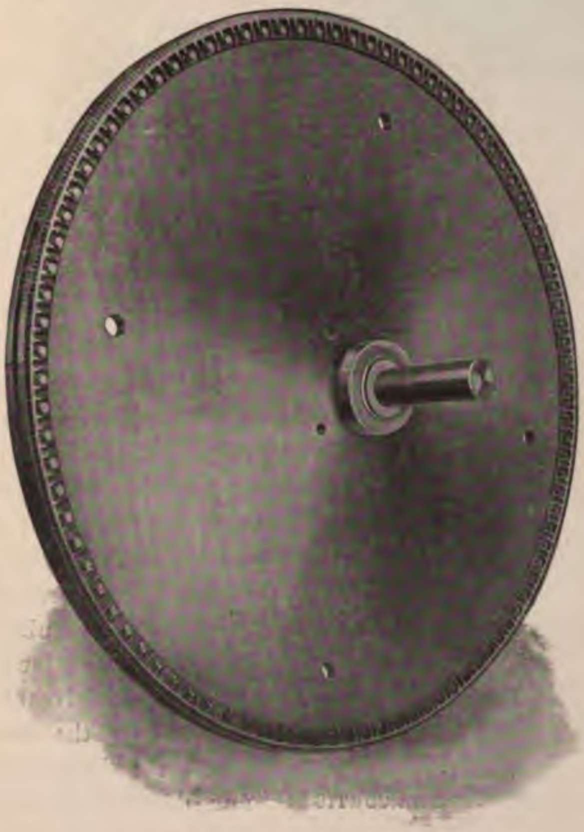
**Vertical Type.** For turbines of large capacity the General Electric Company has applied these principles to a turbine with a vertical shaft, to avoid all imposition of weight on cylindrical bearings and tendency to shaft deflection as well as all difficulties due to irregularity of expansion or imperfections of support. The turbine is compact and of the greatest mechanical simplicity.

**Step-Bearing.** The step-bearing at the end of the vertical shaft supports the revolving part and maintains the revolving and stationary elements in exact relation. It consists of two cylindrical, cast-iron plates bearing upon each other and with a central recess to receive the lubricating fluid, which is forced in by pumps with a pressure sufficient to sustain the weight of the revolving part. It is apparent that the entire weight of the machine is thus carried upon a film of lubricating fluid and that there is no appreciable friction. When the flow of liquid is interrupted, the bearing is slowly worn away, but experience has shown that interruptions in the flow seldom cause any deterioration which prevents the continuance of the machine in service after the flow is re-established. The tendency of the bearing in such cases is to wear itself to a new surface so that it operates normally.

NOZZLE.

All large steam turbines are necessarily dependent upon forced lubrication. Failure of lubrication in a horizontal turbine is liable to cause serious trouble through cutting of the shaft or interference with the alignment. In the Curtis vertical type the possibility of any trouble is minimized and the simple cast-iron blocks can readily be replaced at trifling expense. In large stations, where several turbines are operated, it is desirable to install weighted accumulators which will maintain a constant pressure and also act as a reserve.

**Clearances.** In consequence of the exact relation maintained between the revolving and stationary elements by the step-bearing, it is possible to operate the turbines with very small clearances between the moving and stationary buckets. Experience, however, has shown that the reduction of clearance beyond a certain point, is not beneficial, and that clearances less than those which are desirable for economical reasons can be used without mechanical difficulty.



REVOLVING WHEEL FOR 2000 KW. CURTIS STEAM TURBINE.

**Balance.** A most important matter in all steam turbine work is the balance; and the importance of good balance applies as well to vertical turbines as those that are operated in a horizontal position. When the balance is good, the bearings on the vertical turbine shaft are practically free from strain or friction. It is possible to operate these machines successfully with a considerable imperfection of balance, but a perfect balance is practicable and should be attained in every case.

**Governing.** The speed of these turbines with variable load is controlled by the automatic opening and closing of the original admission nozzle sections. A centrifugal governor, attached to the top of the shaft, imparts motion to levers which in turn work the

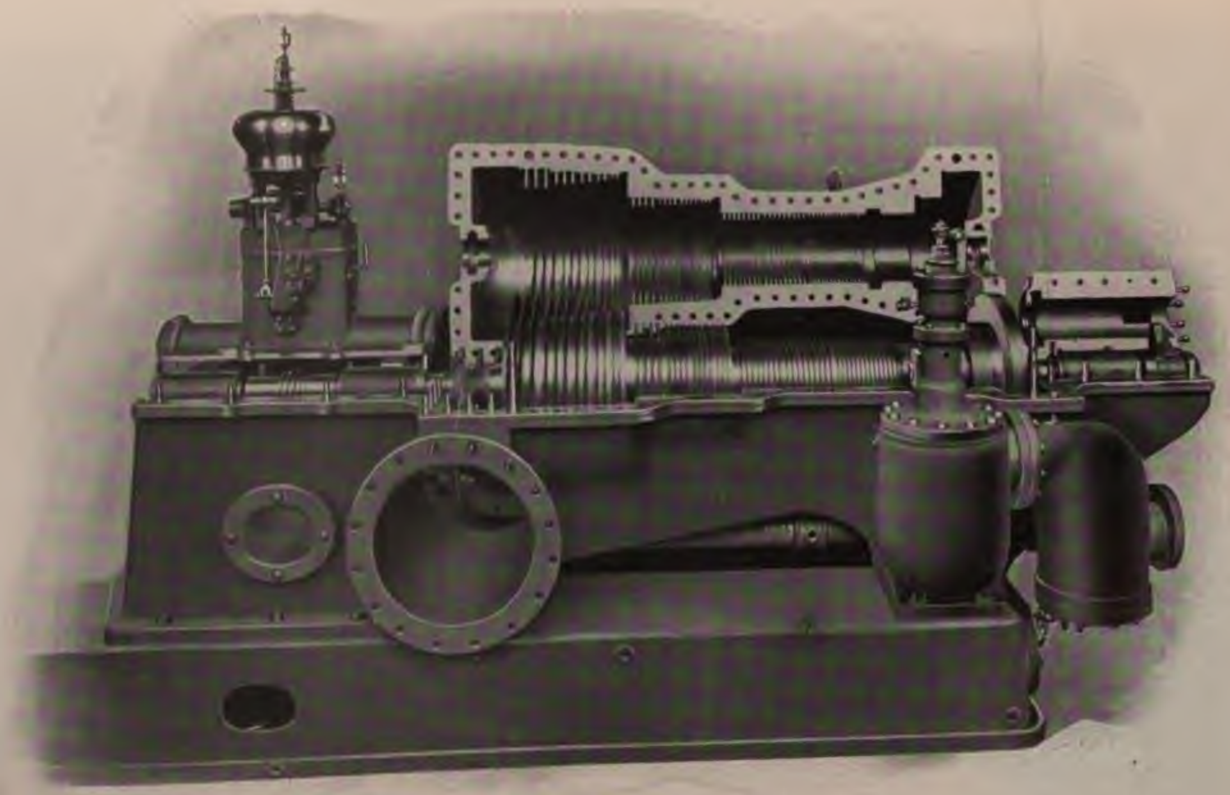
STATIONARY BUCKETS FOR CURTIS STEAM TURBINE.

valve mechanism. There are several valves, each communicating with a single nozzle section, or in some cases two or more nozzle sections. These valves are connected to long pistons, by which the valve can be opened or closed by steam. The motion of each of these pistons is controlled by a small pilot valve which is worked by the governor mechanism. The movement of the governor mechanism moves the pilot valves successively and the main valves are opened or closed by the steam. By suitable adjustment, almost any degree of accuracy in speed control is obtainable.

REVOLVING BUCKETS FOR CURTIS STEAM TURBINE.

The steam consumption of turbines is naturally dependent upon speed, size, and other conditions, and varies in different individual designs. Machines of this type show excellent results as compared with other turbines and engines, the light-load and overload efficiency being a marked advantage. The guarantees of steam economy made by the General Electric Company are based upon results obtained with machines in operation.

**Condensers.** The larger sizes of Curtis turbines are designed to operate condensing, but they are all adapted to operate non-



600 HORSE-POWER TURBINE OPEN FOR INSPECTION.

condensing, and when thus operated will carry full rated load. These turbines are designed to utilize the expansion of the steam to a high degree of vacuum, and the use of good condensing facilities is therefore desirable.

When surface condensers are used, the condensed water can be returned directly to the boilers, as it is entirely free from oil.

GOVERNOR FOR 5000 KW. TURBINE.

Experience shows that distilled water free from air has no bad effect on boilers. The possibility of so returning water is of the greatest practical value, since deterioration of boilers and inefficiency, through dirt and scale, are serious sources of expense in many power stations. In some types of steam turbines, oil is introduced in connection with balancing pistons or steam packing, and therefore this great advantage cannot be realized.

**Pressure and Superheat.** In these turbines steam is expanded to a considerable degree before it reaches the first buckets. High temperature in the steam is therefore not a source of practical difficulty, and steam of very high pressure and high degree of super-

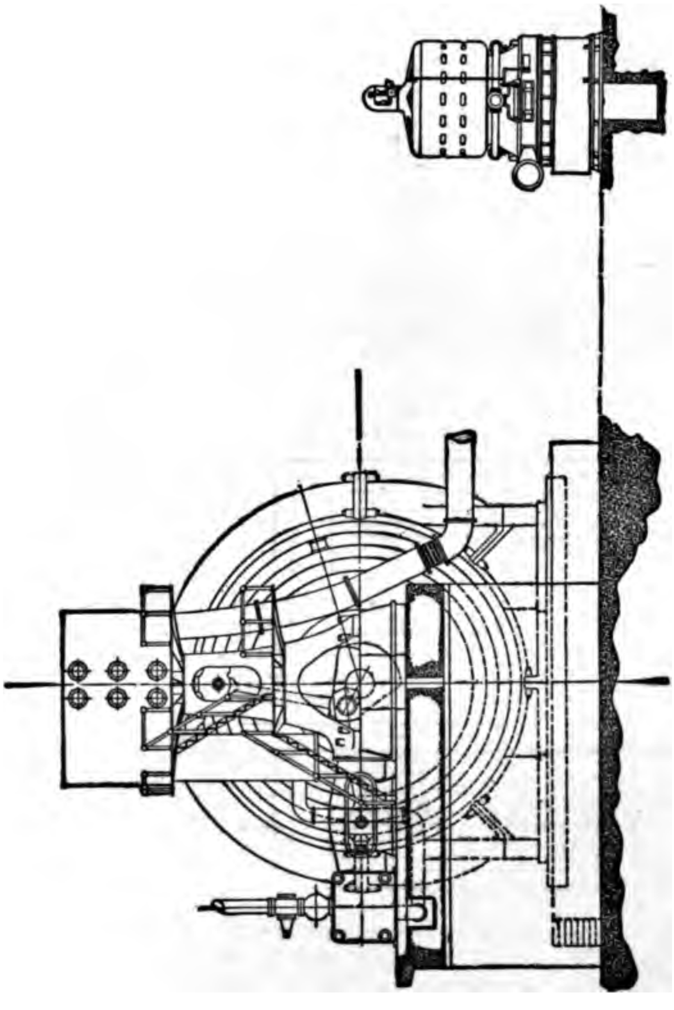
500 KW CURTIS STEAM TURBINE IN COURSE OF CONSTRUCTION.

heat can be used. The reduction in steam consumption by superheat or increased pressure is as great in the Curtis turbine as in any form of steam engine.

**Wear on Buckets.** The question is sometimes raised as to the rate of deterioration through erosion of the buckets in the Curtis Steam Turbine. Experiments show conclusively that while the wear varies with different degrees of moisture in the steam and with different degrees of steam pressure, it is in any event negligible from the standpoint of maintenance. All buckets in the Curtis turbine can be renewed without difficulty and at small expense. In the lower pressure stages, where the density of the steam is less, no wear has been perceptible.

**Applications.** The speeds adopted for the Curtis turbines are such as to give the best results in the design of the generators; consequently the General Electric generators designed for operation with turbines have high efficiency, and are so proportioned that they will carry heavy overloads without injurious heating. These turbines are built in sizes ranging from $1\frac{1}{2}$ Kw. to 5,000 Kw.

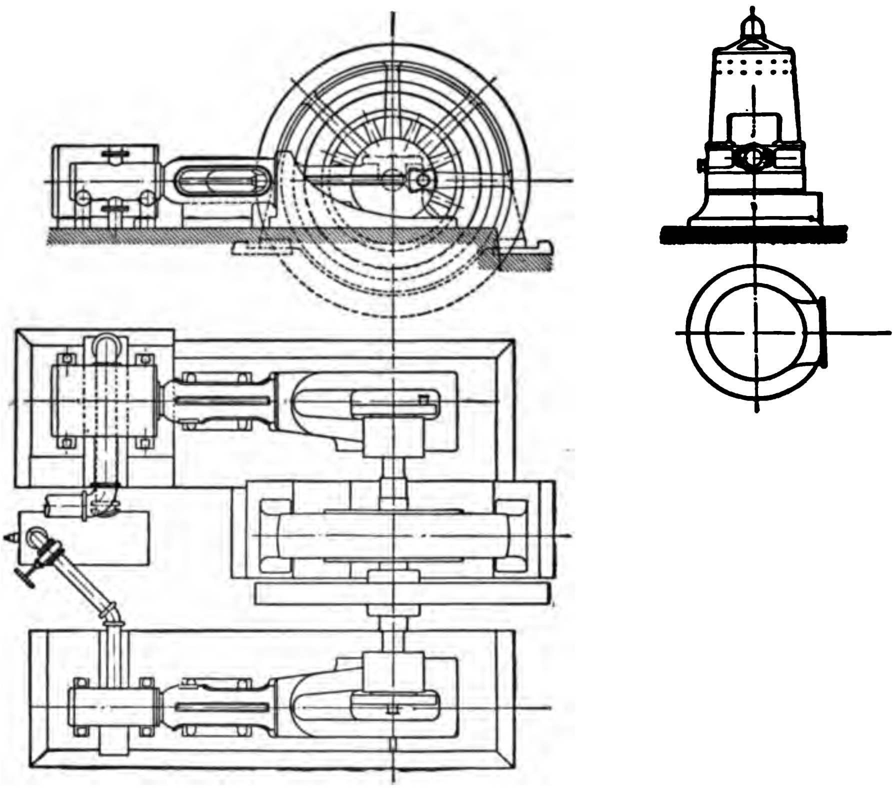
The Curtis turbine is also suitable for driving centrifugal



COMPARISON OF 500 KW. CORLISS ENGINE AND 500 KW. CURTIS TURBINE.

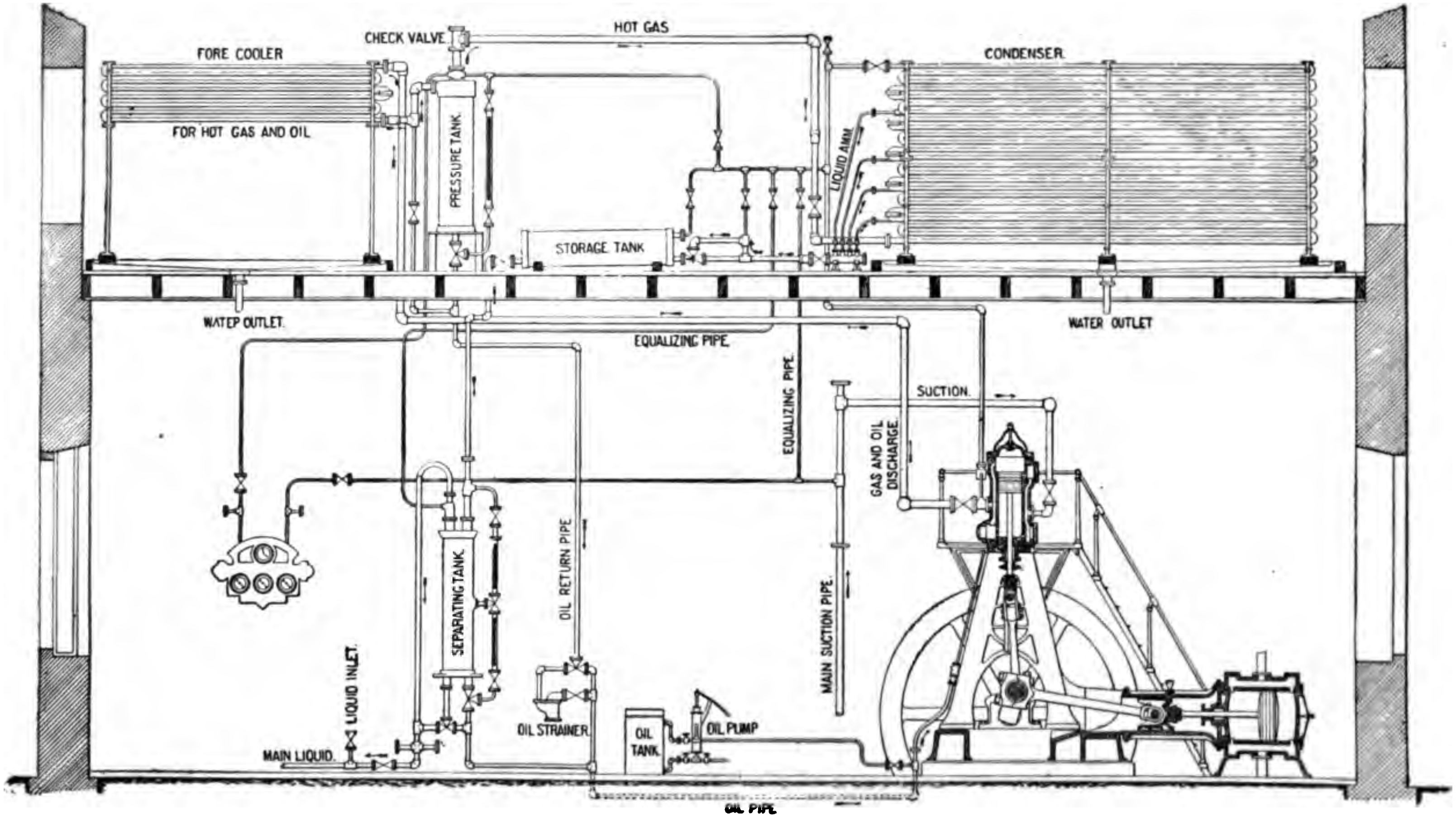
pumps, blowers, fans, and other similar apparatus. Turbines for such applications are being rapidly developed. In order to meet the demand for small direct-current turbines to be used for exciters, train lighting, and isolated lighting, a complete line of non-condensing horizontal shaft turbines has been developed, ranging in capacity from 1½ Kw. to 300 Kw. These machines are designed to operate at low shaft speed without the use of gearing and show relatively high steam economy when operating non-condensing. They are self-contained and are automatic in regulation.

The machine shown in the accompanying diagram has been tested under a variety of conditions at Newport, and has given



COMPARISON OF 500 KW CROSS-COMPOUND ENGINE AND 500 KW. CURTIS TURBINE.

results which illustrate very well the advantage of this type. Among other tests that were made, the machine was operated on a rapidly changing railway load; the momentary variations of load amounting to about 120 Kw. In one test the average load carried with this fluctuation was 250 Kw., and the steam consumption was 24.4 pounds per Kw. hour output, with saturated steam. Another test was one with similar fluctuations and with an average of 421 Kw. The steam consumption under this condition was 20.7 pounds of saturated steam per Kw. hour output. The best reciprocating engine under conditions of the first test would probably consume from 28 to 30 pounds per Kw. hour.




De La Vergne Refrigerating Plant.

# REFRIGERATION.

Refrigeration may be defined as the process of cooling. It is artificially or mechanically performed by transferring the heat contained in one body to another, thereby producing a condition commonly called cold, but which is in fact an absence of heat. This transfer of heat is most rapidly and economically accomplished by evaporation, but before considering the apparatus used a few important definitions should be reviewed.

**Unit of Refrigeration.** The unit or basis of measurement of refrigeration, is the unit of heat, and in the United States and England is the British thermal unit (B. T. U.) which is equivalent to raising or lowering the temperature of one pound of water 1° Fahrenheit when at or near 60° Fahrenheit.

**Specific Heat.** Specific Heat, or capacity for heat, is the relative capacity of a substance for heat, and is stated or expressed relative to that of water, since water has the greatest heat capacity of any known substance except Hydrogen.

**Latent Heat.** When a body changes from a solid to a liquid, or a liquid to a gaseous state, a certain amount of heat must be supplied to it in order to effect the change. This amount is called its latent heat, and is expressed in thermal units. Thus we have in the melting of one pound of ice a latent heat of 142 thermal units, and we understand by this that in order to melt a pound of ice it must absorb into itself, in making the change, 142 B. T. U., or the equivalent of one pound of water changing 142 degrees Fahrenheit.

**Units of Machines or Plants.** The unit (or capacity) of refrigerating plants is ordinarily stated in tons, that is, the equivalent of so many tons of ice (of 2000 pounds) at 32° F melted into water at 32° F. The unit is equivalent to $142\times2000=284{,}000$ British thermal units.

**Thermometers.** For ordinary use, a mercury tube having a graduated surface or scale at its back with a bulb at its lower end and containing a quantity of mercury is used to denote the temperature of its surroundings.

Two different scales are commonly used in the refrigerating industries: the Fahrenheit and Reaumer. The Centigrade or French standard is used for chemical or technical purposes. In the United States and England the Fahrenheit scale is generally accepted as standard except in breweries where the German or Reaumer scale is quite often found.

The **Fahrenheit** scale is divided in such manner that the boiling point of water at atmospheric pressure is 212° and the freezing point 32°. It is said that 0° F was the lowest temperature Fahrenheit was able to produce by the melting of ice by salt.

The **Reaumer** scale is graduated by making the boiling point of water 80° while the freezing point is at 0°.

The **Centigrade** has the freezing point of water at 0° as the Reaumer, while the boiling point is fixed at 100°. This graduation is typical of the French system of measurement.

Fig. 1.

To transpose the temperature of one scale to that of the others the table on page 77 will be found convenient.

Let us now take an illustration from a branch of engineering with which almost every one is familiar.

If we place a glass of water in contact with heat at a temperature of 212° F or more, heat will pass from the source and be absorbed by the water until its own temperature reaches that of 212°, after which evaporation of the water commences and continues until the water has all been transformed into steam. During this time an amount of heat corresponding to this duty has been transferred from the source of heat to the water and its vapor called steam. This process is familiar to all engineers, in the steam boiler, and is similar to that of refrigeration as ordinarily applied, except that the one is going on at or above a temperature of 212° F (the boiling point of water) while refrigeration is accomplished by the evaporation of a liquid having a boiling or evaporporating point sufficiently low to obtain the desired temperature.

**Agents.** Among the most commonly used agents for obtaining artificial refrigeration may be mentioned Ammonia, Carbonic Acid, Sulphur Dioxide and Compressed Air, the first named being the most generally used and approved, while the others have advantages for use on ship-board and other places where the fumes of ammonia would prove objectionable. Ammonia, however, appears to present the most favorable qualities for general use, and will, therefore, be the principal agent considered.

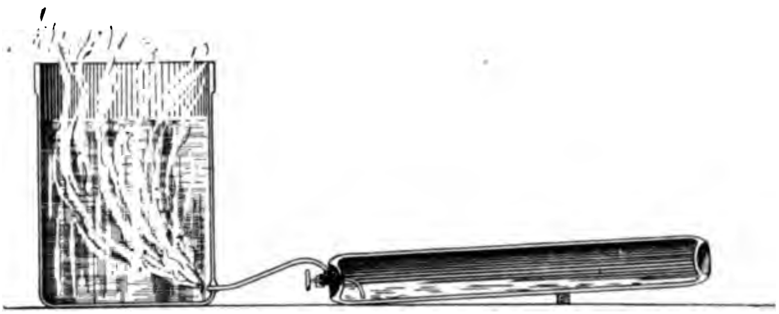


Fig. 2.

Of the two types of ammonia machines, the absorption and the compression, the latter will be the first described. The primitive process of refrigeration is represented by a glass or receptacle (Fig. 1) in which a quantity of anhydrous ammonia is placed, and which, so long as its own temperature and that of its surroundings remain at or above—28° F or 28° below zero (its boiling point) will continue to take heat over to itself, and therefore continue to evaporate and produce a cooling effect upon its surroundings, or what is commonly known as refrigeration in the body or substance with which it is in contact.

In Fig. 2 we have such a receptacle to which is attached a drum or flask filled with the refrigerating agent; if it were possible to procure a cheap volatile liquid, having a sufficiently low

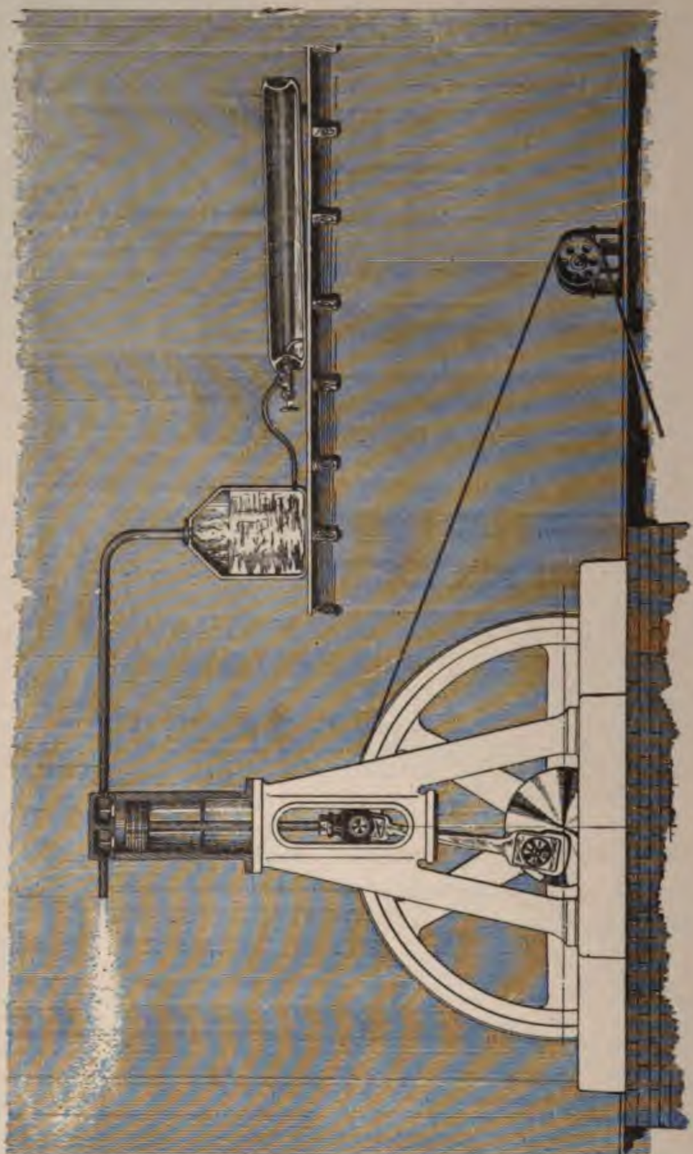


Fig. 3.

boiling or evaporating point, the complex systems of refrigeration would be reduced to the above parts, or equivalent simple system. The system would consist of an evaporator, and a receptacle for the refrigerant, with a connecting pipe between, provided with an expansion valve to regulate the flow of the liquid to the evaporator. The cost of ammonia or the refrigerating agent renders this waste impracticable, at least at the present time; and to make refrigeration a commercial success it becomes necessary to recover and put in condition to be used again the gases arising from the evaporating ammonia. We have seen how the ammonia absorbed a certain amount of heat from its surroundings during evaporation; it is evident that this heat must be taken from it before it can be again effective as a refrigerant, and for this purpose the compressor, condenser and other adjuncts to the plant are required.

The gas pump or compressor is the means employed to recover and compress the gas from the evaporator. In order, therefore, to continue the process of refrigeration in a commercial manner, it becomes necessary to connect to the evaporator and ammonia tank shown in Fig. 2, a gas pump with its engine or other form of power. This is illustrated by Fig. 3. The top of the evaporator is closed and provided with a connecting pipe to the compressor; upon the downward stroke of the compressor piston the gas from the evaporator follows and fills the cylinder above the piston, and upon reaching the bottom of its stroke this valve is closed by a spring, preventing the return of the gas to the evaporator. The return or upward stroke of the piston discharges the gas through the outlet valve and pipe.

Having described the evaporation of the ammonia and recovery of its gases by the compressor, we now supply the apparatus necessary to extract the heat with which it is laden, and thereby cause it to resume its initial state ready to again enter the evaporator and continue the cycle. The apparatus referred to is called the Ammonia Condenser. Fig. 4 illustrates its construction and connection with the balance of the apparatus.

The discharge of the ammonia gas from the compressor is continued through the pipe E, the oil separator F, and into the condenser C, which is composed of a series of pipes over which water flows to take up the heat given out by the compressing of the gas, and which combined effect causes the gas to liquify and flow from the bottom pipe of the condenser through the pipe H to the receiver or storage tank I. This completes the cycle and performs the practical process of refrigeration.

The principle or method of refrigeration has now been de-

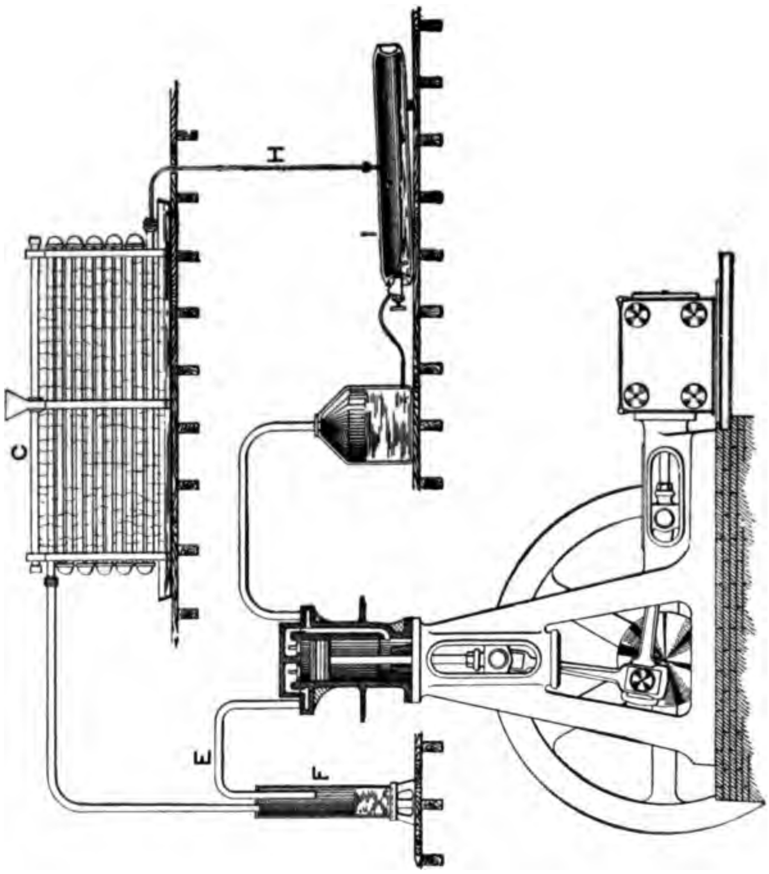



Fig. 4.

scribed without going into details of construction. The next step is the construction, proportion and combination of the several parts making up the refrigerating plant, and as the evaporator is the foundation or basis of the system, let us first consider this part of the plant.

## EVAPORATORS.

Evaporators may be divided into two classes: The first is operated in connection with the brine system. In this evaporator salt brine (or other solution) is reduced in temperature by the evaporation of the ammonia or other refrigerant and the cooled brine circulated through the room or other points to be refrigerated. In the second, the direct-expansion system, the ammonia or refrigerant is taken directly to the point to be cooled, and there evaporated in pipes or other receptacles, in direct contact with the object to be cooled. Which of the two systems is better, is a much disputed and debated point; we can state, in a general way, that

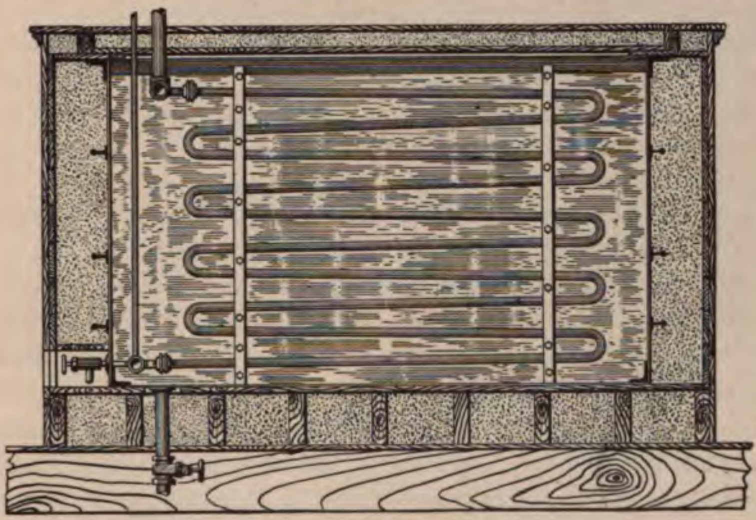


Fig. 5.

both have their advantages, and each is adapted to certain classes of duty.

The cooling of brine in a tank by a series of evaporating coils, (one of the earliest methods) is common to-day. A description of the many methods of construction and equipment would require much space. Let us, therefore, discuss the two most general types only, viz: the rectangular with flat coils, and the circular with spiral coils.

Fig. 5 shows a sectional view of a brine tank. Flat or zigzag evaporating coils are connected to manifolds or headers; the pipe connections leading to and from these manifolds for the proper supplying of the liquid ammonia and the taking away or return of the gas to the compressor are also shown. For coils of this type, 1-inch or $1\frac{1}{4}$-inch pipe is preferable, owing to the impossibility of bending larger sizes to a small enough radius to get the required amount into a tank of reasonable dimensions. It is possible to make coils of this construction of any desired length or number of pipes to the coil, "pipes high," the bends being from $3\frac{1}{2}$ inches to 4 inches centers for 1-inch pipe, and 4 inches to 5 inches for $1\frac{1}{4}$-inch pipe. It is preferable to make the coils of moderate length, (not less than 150 feet in each) and there is no disadvantage (other than in handling) in making them to contain up to 500 or 600 feet each. It will be observed that there is a slight downward pitch to the pipes with a purge valve at the lowest point of the bottom manifold, which is, undoubtedly, valuable and an almost necessary provision. This valve is for removing foreign matter, which may enter the pipes at any time, and by opening the valve and drawing a portion of their contents, the condition of cleanliness can be determined without the necessity of shutting down and removing the brine and ammonia for inspection. The coils are usually strapped or bound with flat bar iron about $\frac{1}{4}$ inch $\times$ 2 inches (or a little heavier for the longer coils) and bolted together with $\frac{1}{2}$-inch square-head machine bolts. The coils are painted with some good water-proof or iron paint.

The brine tank is usually constructed of iron or steel plates, varying from $\frac{3}{16}$ inch to $\frac{3}{8}$ inch in thickness; the average being $\frac{1}{4}$ inch for tanks of ordinary size. The workmanship and material for a tank for this purpose should be of the very best; without these the result is almost certain to be disastrous to the owner or builder. The general opinion with iron workers (before they have had experience) is that it is a simple matter to make a tank which will hold water or brine, and that any kind of seam or workmanship will be good enough for the purpose. On the contrary the greatest care and attention to detail is necessary. It is customary, and good practice, to form the two side edges at the bottom by bending the sheets, thereby avoiding seams on two sides, while for the ends an angle iron may be bent to conform to this shape and the two sheets then riveted to the flanges of the angle iron. The edges of the sheets should be sheared or planed bevel, and after riveting, calked inside and out with a round-nosed calking tool. The rivets should be of full size, as specified for boiler construction and of length sufficient to form a full conical head of height equal to the diameter of the rivet and brought well down onto the sheet at its edges. An angle iron of about 3 inches should be placed around the top edge, and riveted to the side at about 12-inch centers.

One or more braces (depending on the depth) should extend around the tank between the top and bottom, to prevent bulging; without these it would be impossible to make the tank remain tight, as a constant strain is on all its seams. A very good brace for the purpose is a deck beam. Flat bar iron placed edge-wise against the tank with an angle iron on each side and all riveted through and to the side of the tank with splice plates at the corners or one of each pair long enough to lap over the other makes a good brace; heavy T-iron is also used to some extent. It is usual to rivet up the bottom of the tank and a short distance up the sides, then test by filling with water; if tight lower to its foundation and complete the riveting and calking. It may then be filled with water and tested until proven absolutely tight, when it may be painted with some good iron paint; it is now ready for its equipment of coils and insulation.

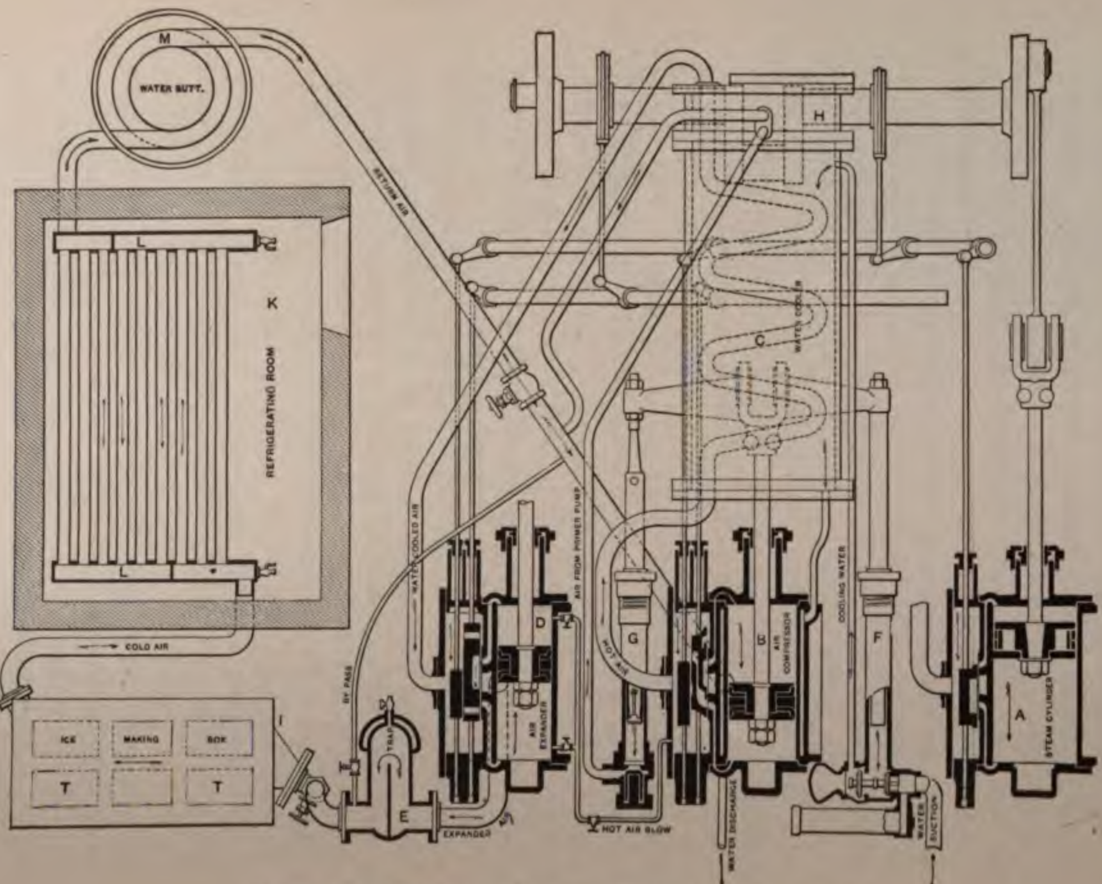
A washout opening with stop valve should be placed in the bottom at one corner; for this purpose it is well to have a wrought iron flange, tapped for the size of pipe required and riveted to the outside of the bottom. If the brine pump can be located at this time, it is well to have a similar flange for the suction pipe riveted to the side or bottom of the tank, as a bolted flange with a gasket is never as durable as a flange put on in this manner.

Assuming that the tank is now absolutely tight and painted, the insulation may be put around it, the insulated base or foundation having been put in previous to the arrival of the tank. The insulation should be constructed of joists 2 inches or 3 inches × 12 inches on edge and filled in with any good insulating material and floored over with two thicknesses tongued and grooved flooring with paper between. In putting the insulation on the sides and ends of the tank, place joists 3 inches × 4 inches resting on the projecting edges of the foundation about 2 feet apart. The upper ends should be secured to the angle iron at the top of the tank, its upper flange having been punched with ⅝-inch holes 18 inches to 24 inches centers and to which it is well to bolt a plank, having its edge project the required distance to receive the uprights. Between the braces around the tank blockings should be fitted to secure the frame work at the middle, as the height of some tanks is too great to depend on the support at top and bottom alone.

After the frame work has been properly formed and secured to the base and tank, take 1-inch flooring, rough, or planed on one side, and board up on the outside of the uprights, filling in as the work progresses with the insulating material which may be any one of the usual materials, granulated cork being about the best, all things considered, although charcoal, dry shavings, saw-dust, or other non-conductors may be used with good results. When the first course of boards is in place it is well to tack one or two thicknesses of good insulating paper against the outer surface, care being taken that the joints lap well and that bottoms and corners are filled and turned under at the junction with the bottom insulation. It is then in shape for the final or outer course which is very often made of some of the hard woods in 2½-inch or 3-inch widths, tongued, grooved and beaded and finished off with a base board at the bottom and moulding at the top, and given a hard wood finish in oil or varnish. If the tank is located in a part of the building in which appearance is of no importance, the outer course may be a repetition of the first, except that the boards are put on vertically instead of horizontally.

It is well to make the top of the tank in removable sections to facilitate examination or cleaning; for this purpose make a number of sections about 2½ to 3 feet wide of the length or width of the tank, using joists about 2 inches × 6 inches placed on edge, floored over top and bottom and filled in with the selected insulating material. It is also well to have a small lid at one end of each (preferably over the headers or manifolds) which will allow of internal examination of the tank to ascertain the height or strength of brine without removing the larger sections. The tank is now fully equipped and ready for testing and filling with brine.

For a circular tank the general instructions regarding construction and insulation may apply as with the rectangular tank




PLAN AND SECTION OF ALLEN DENSE-AIR ICE MACHINE.

just described; therefore only its special features will be considered. If the tank is small and there is sufficient head room above it for handling the coils there cannot be serious objection to this type as its cost is lower than that of the rectangular tank. This is often an important item in a small installation, but when the tank is of considerable size and the coils large it is not as readily

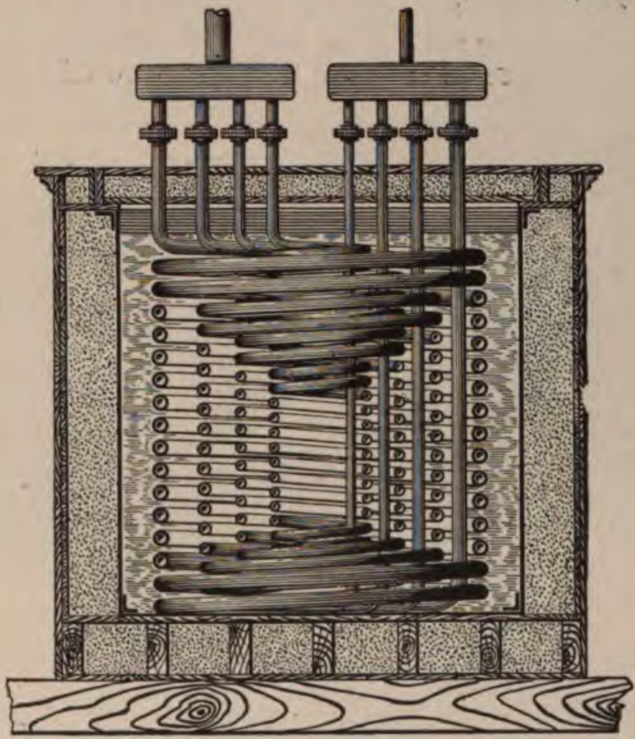


Fig. 6.

handled and taken care of as the other type. The usual construction of a nest of coils for a round tank is to bend the inside coil to as small a circle as possible, which, if it be of 1-inch or $1\frac{1}{4}$-inch pipe may be 6 to 8 inches. Increase each successive coil enough to pass over the next smaller until the required amount of pipe is obtained. The ends may then be bent up or out and joined to headers at top and bottom and the tank insulated in the manner previously described; it is then ready to test and charge with ammonia and brine. Fig. 6 represents an evaporator of this type.

Other constructions of tanks and coils are too numerous to describe in detail, and with one exception may be properly classed in one of the preceding types. The one exception referred to is illustrated in Fig. 7. It is quite common and is adopted for large pipe and is often called oval, although not of that shape, but rather a combination of the flat and circular form. It has some good features; it allows the maximum amount of pipe in the smallest space and a large amount of pipe in a single coil.

**The Brine Cooler** at present is a popular and efficient method

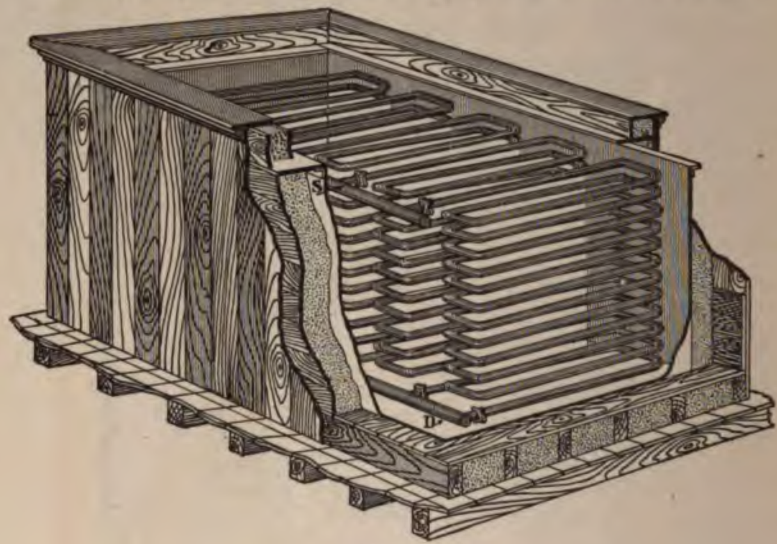



Fig. 7.

of cooling brine for general purposes. Owing to mechanical defects and the impossibility of obtaining a brine solution which would not freeze, it was abandoned only to be taken up again, and with the aid of modern ideas and better material it has become highly successful. Unlike the brine tank and coil method of refrigeration, in which the ammonia is evaporated within the coils while the brine surrounds them, the brine passes through a series of coils and the ammonia evaporates within a wrought or cast snell surrounding the coils. Thus the action is reversed.

Fig. 8 is what is known as the **enclosed-shell type** of brine cooler, A representing a cast or wrought-iron shell, flanged at each end, to which heads are bolted; a tongue and grooved joint between, makes the closed cylinder gas tight. B is a series of welded extra strong pipe coils, one within the other, having their ends project through the heads and joined to headers at each end with proper unions; a stop valve is supplied to each coil. Lock nuts or glands are placed around each coil at its opening through the heads and one or more glass gauges with the usual gauge fittings are tapped into the side of the shell to indicate the amount of ammonia. Liquid ammonia is fed into the shell by an ordinary expansion or feed valve near the lower end of the shell at C and the gas taken off through the opening and pipe D to the compressor. A purge valve E for drawing off impurities is placed at the lowest point in the bottom head and a second one F for gas or air in the top head.

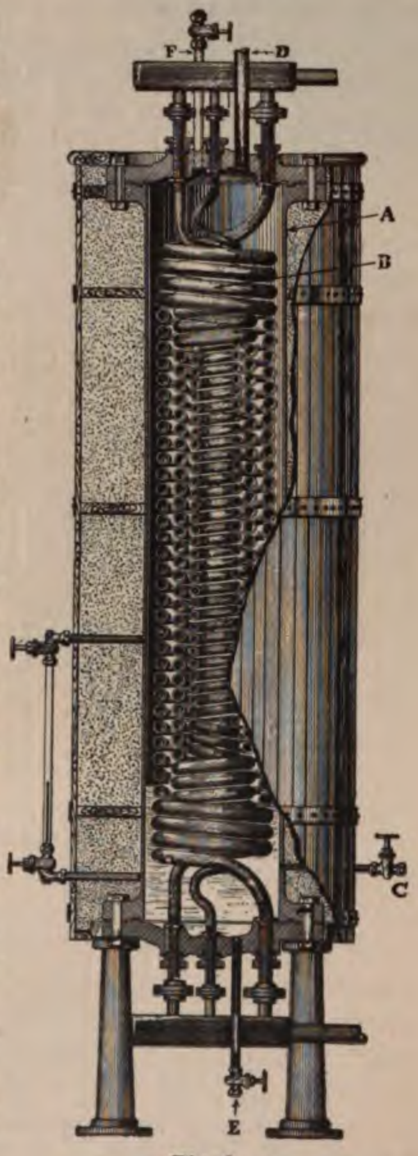


Fig. 8.

In operation, the discharge pipe from the brine pump is connected to the top header or manifold, and the bottom header is connected to the main leading to the refrigeration to be performed; the return from the cooling system is generally brought to a medium-sized brine tank without coils to which the suction of the pump is connected, thereby completing the brine circuit. The heat of the brine passing through the coils in the cooler is taken up by the ammonia during evaporation; the

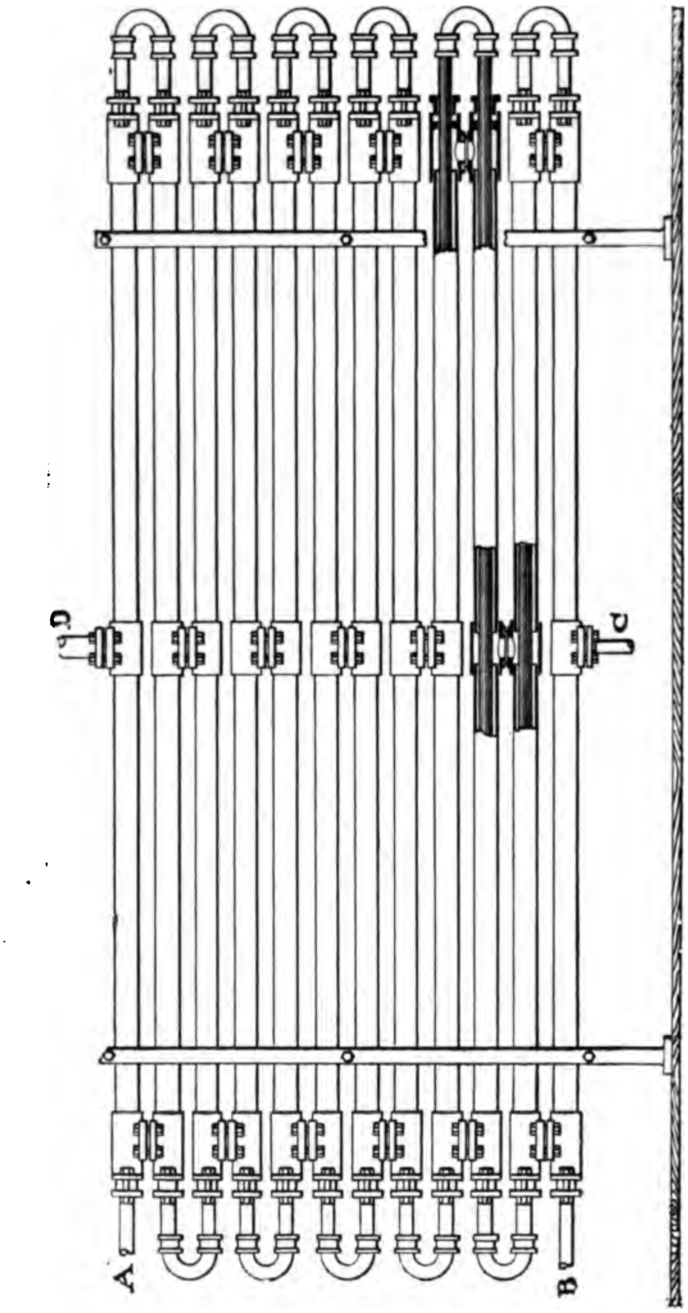



Fig. 9.

gas is taken away from the top of the shell to the compressor, and discharged to the condenser and into the receiver to be re-used, as with the system illustrated by Fig. 4.

The advantages of the brine cooler over the brine tank are due to two features of construction. The brine in passing through the coils is divided into a number of small streams, and while flowing rapidly through a coil of considerable length is churned to such an extent that it is all brought in contact with the coil, of which the outer surface is exposed to the temperature of the evaporating or boiling ammonia, and thereby gives up its heat much more rapidly to the ammonia than in the brine tank. In the brine tank there is a large body of brine with scarcely any movement; the brine immediately in contact with the pipe may be quite cold, but becomes warmer as the distance from the pipe increases.

The second advantage is that during the evaporation of the ammonia a violent ebullition is taking place, and if this is confined within the pipe coil a certain amount of the liquid is carried forward by the escaping gas, and the evaporation within the coil is limited. This limit is reached when the vapor enters the compressor in such quantities as to cause too great an expansion in the compressor, or when it becomes difficult to keep the stuffing-box tight, while in the brine cooler properly constructed, the larger diameter of shell allows evaporation to take place up to practically the theoretical boiling point of the ammonia, without the liquid being carried forward through the gas pipe to the compressor. This permits a much higher evaporating pressure or "back pressure" as it is commonly called, than with the brine tank and coils. Also the concentrated or compact shape and construction of the cooler allows greater economy than the large radiating surface of the brine tank. The sides and end of the cooler are insulated by some one of the usual methods and very often lagged with finished hardwood strips, tongue, grooved and beaded and bound with finished brass or nickel plated bands.

Salt brine is commonly used in the brine tank and coil form of refrigerator, but it is unsafe to use it with the brine cooler because when passing through the coil it may freeze and burst the coil. A solution of chloride of calcium is commonly used, its freezing point being 54° below zero Fahr. while salt brine is practically 0° Fahr.

The second form of brine cooler is what is known as the **double-pipe type**, the construction of which is illustrated in Fig. 9, In this type one pipe is within another, the brine being discharged from the pump into one or more pipes at A and issuing at B. This connection leads from the main to the point to be refrigerated and the ammonia is expanded or fed into the annular space between the two pipes, and takes up the heat of the brine in evaporating and issuing as gas from the opening D at the top of the cooler. From thence the ammonia passes to the compressor and through the cycle of compression, condensation and return to the liquid ammonia receiver as before. The ammonia evaporating between the two pipes will naturally absorb as much heat from the outside surface as from the inner or brine if allowed to do so, and it therefore becomes necessary to insulate the outside of this from exterior influences. As it is practically impossible to cover the bends and irregular surfaces it becomes necessary to build an insulated room in which the cooler is erected. This is commonly done, but some authorities do not consider it the most practical form. The cooler is equipped with the necessary stands, manifolds and stop valves to properly control the action of any one section when more than one is used.

As with the enclosed brine cooler, previously described, chloride of calcium brine should be used, as there exists the same liability to freeze, and it is unsafe to operate either type with the ordinary salt solution. These two types of brine coolers and brine tanks and coils are the usual means of cooling or refrigerating brine.

## COMPRESSORS.

The next step in the process is the recovering of the evaporate ammonia and its return in liquid form. Compressors may be divided into two principal classes, single acting and double acting; and each class subdivided into vertical and horizontal. They are of the vertical type if single acting, and of both vertical and horizontal if double acting, although the majority of the double acting are of the horizontal type. Machines may also be classed according to the form of driving. The engines used may be horizontal or vertical, and within this classification comes almost any machine of modern build.

Fig. 10 illustrates the vertical single-acting type of compressor, two in number, in combination with and driven by a horizontal Corliss engine. It embodies the necessary and usual requisites of an efficient gas pump or compressor.

As already stated, the function of the compressor is to recover the gas from the evaporator and compress it into the condenser at a pressure which will cause it to liquify under the action of the cooling water. It is evident that the gas must follow the piston in its downward stroke and fill the compressor, and upon its reaching the end of its stroke and the pressure being balanced, the strength of the spring in the suction valve causes it to close and the piston begins its return stroke. The compression of the gas within the compressor takes place until its pressure equals or slightly exceeds that above the discharge valve; it then opens and the compressed gas flows into the discharge pipe and thence to the condenser. Two compressors of the single-acting type are almost always used in a machine of this type, and the cranks set opposite, or at 90° to one another, so that one compressor is filling and one compressing and discharging at each half revolution of the crank shaft, and the load is accordingly divided into two units, either one of which may be operated independently if necessary.

As the evaporator is the heart of the refrigerating system, so the piston and valves are the heart of the compressor, and the principal, almost the only, cause of difficulty in the action of the compressor will be found to be in one of the two.

In the compressor in which the valves operate in a cage, there must of necessity be a gas-tight joint between the bottom of this cage and the compressor head or piston in which it is located; this joint is made in a variety of ways, any one of which will prove effective. A square shoulder is cut into the head with a corresponding shoulder on the cage to match, and a lead gasket about $\frac{1}{16}$ to $\frac{1}{8}$ inch in thickness placed between the two. This makes a durable joint, except in cases where the joint between the two is of such an amount that the lead is constantly pressed through (a disadvantage of lead as a gasket material). Without

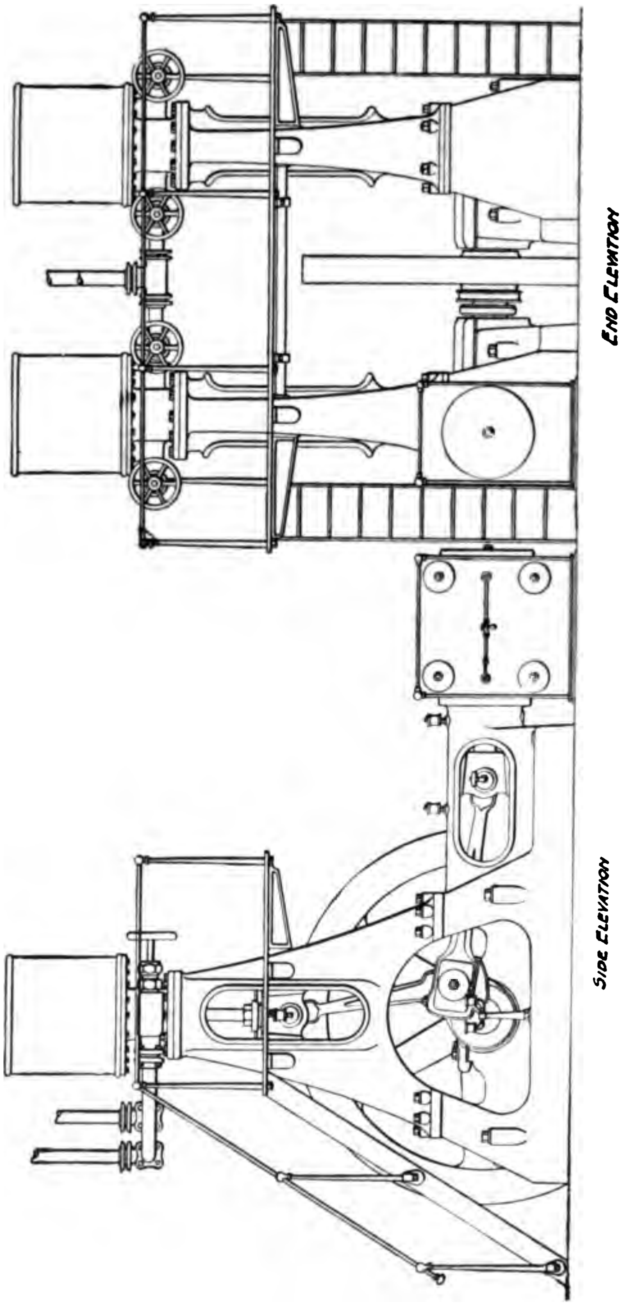



Fig. 10.

one's being aware of the fact, the gasket is gone and a leakage exists. Another objection to a lead gasket is that it compresses and *knits* into the interstices between the cage and the head. This often makes it impossible to remove the valve or cage from the head without the aid of some kind of a chain block or tackle. Another form of gasket for this purpose, but not popular from a lack of confidence in its permanency, is common lamp or candle wicking saturated with oil and wound tightly and smoothly in the corner against the shoulder on the cage. It is put in place and fully compressed by pulling down on the valve cap until the cage is at the desired height. It is good practice to wind enough on until, when the cage is pressed down by hand, it stands about $\frac{1}{16}$ inch above the surface of the head at the top; this amount of compression would make it about even when pulled down. As already stated, this kind of packing is not very popular on account of lack of durability, but it gives very satisfactory results when properly applied, and the valve and cage may be easily removed. Recently the gasket has been omitted and a ground joint made between the cage and the head. Although its efficiency has not yet been proven, from present indications it should be both satisfactory and permanent.

Assuming that we have made the joint between the cage and the compressor head gas-tight, we must also be certain that the compressor valve forms a perfect joint in closing against the cage. In a vertical compressor, in which the action of the valves is also vertical within their cages, the conditions naturally favor this to the greatest possible extent, as in closing they drop to their seats and it is only necessary to provide for the slight wear taking place in the stems and on the seats due to the rapid opening and closing of the valves. The valve stem must necessarily fit the guides in the cage as closely as possible and still allow free movement, and the seat between the valve disc and cage (preferably made at an angle of 45°) must first be machined to the proper angle and then ground in the usual manner. Having made it impossible for the gas to pass the valves and cages, means must be provided for closing the valves at the proper time to prevent loss, as a valve which is slow in reaching its seat presents a double evil—loss of efficiency and improper or irregular action on the balance of the machine. The spring is the usual means of operating the compressor valve, and, on the suction or inlet, is commonly placed between the top of the cage and underneath a washer placed at the end of the stem and held in place with one or two nuts; it is frequently reinforced with a buffer spring, or one of greater strength, enough shorter than the length of the stems to allow its opening the proper distance, and then stopping the travel of the valve gently.

**Valves.** Fig. 11 illustrates a type of inlet valve which has stood the test for years and embodies many good qualities. The different points referred to are indicated by the following letters: A, the joint between the cage and head; B, the contact between the valve disc and the cage; C, the spring for actuating the valve, and D, the buffer or stop spring to stop the travel of the valve at the proper point of opening, In the use of this valve the requirements are that it shall admit the gas to the compressor during the downward stroke of the piston, and close while the piston is at the bottom of stroke and the crank pin is passing the bottom center. It will, therefore, be readily understood that if the spring is stronger than necessary, it will require a certain amount of the pressure of the gas to overcome the strength of the spring, and prevent the filling of the compressor to its fullest limit. In the closing of the valve it would be driven with considerable force against its seat, making a noise in so doing and causing excessive wear. Considerable skill and experience are required to obtain perfect results, but with good judgment and a few trials most of the imperfections can be overcome. Generally the closing spring should not be stronger than is necessary to close the valve when held vertically in the position in which it naturally rests. By taking the valve and cages in the hands and pressing down on the top of the stem with one of the fingers, it will be readily ascertained when the springs are of proper strength to close the valve. When put on the compressor, so far as the operation of the inlet valves is concerned, the machine will be practically noiseless and effective in the admission and retention of the gas from that side.

The discharge valve operates in the reverse direction to that of the suction valve. We know that the suction valve closes while the compressor piston is at its lowest position in the compressor and while the crank is passing its bottom center. The piston now moves upward compressing the gas until it reaches the pressure in the ammonia condenser, and as it passes this point far enough to overcome the tension of the spring on the discharge valve, it causes it to lift and the contents of the cylinder in its compressed state are discharged through the discharge pipe into the condenser. This continues until the piston reaches its highest

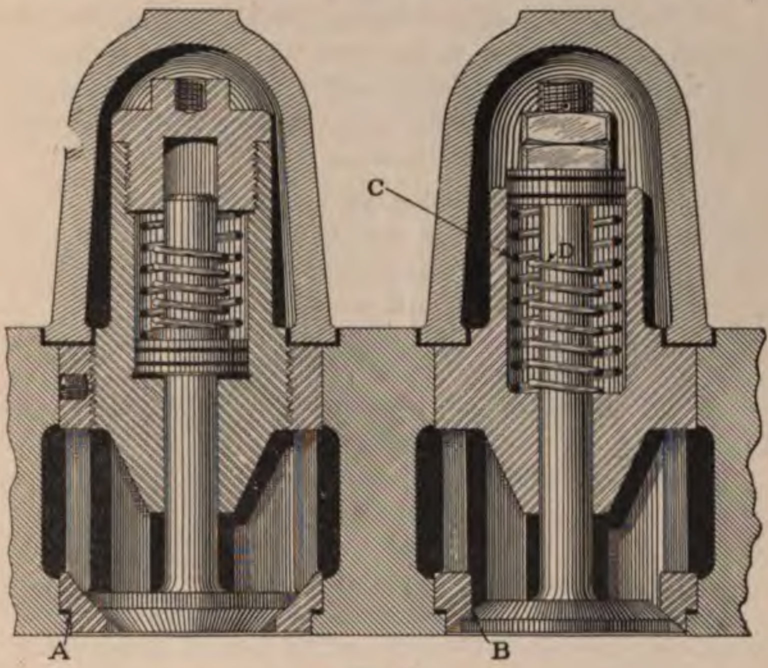



Fig. 11.

point and the crank is passing its top center, at which point the valve closes and the suction valve again opens to admit an additional amount of the gas. This process is continued during the operation of the apparatus.

It will be noticed that the suction valve opens and closes while the piston is practically without motion, but the discharge valve opens while the piston is nearly at its maximum, and closes while the piston is at the minimum speed. From this it will be apparent that the thrust or effort on the discharge valve is much greater than on the inlet, that is, in an upward or outward direction; hence the device for arresting the upward motion of the valve must be more effective than the other. Also the valve must close in a shorter space of time because the great pressure above the valve would cause it to fall with considerable force were it not to reach its seat while the piston was still at the top of its travel, and the pressure above and below equal. Should the piston begin its return or downward stroke before the valve closes it would have the condensing pressure above, and the inlet pressure below, a difference of from 150 to 175 pounds. This pressure would cause it to seat with an excessive blow which would soon cause its destruction, and also cause the escape of a portion of the compressed gas into the compressor resulting in great loss in efficiency of the machine.

To stop the valve in its opening and prevent shock, it is necessary to provide a buffer or cushion in addition to the spring used to close it. The cushion, as usually constructed, is a piston fitting closely in a cylinder and provided with openings for the escape of the gas in front of the piston until it reaches a certain height, which should conform to the lift of the valve; at this point the piston is prevented from traveling farther by the compression of the gas and the valve is brought to a stop without noise or jar.

The strength of spring for closing the discharge valve must be nicely gauged; if too light the valve will not be brought to its seat until the piston has started on the return stroke, causing a return to the compressor of a portion of the compressed gas, and the striking on the seat with considerable force due to the pressure of the gas above the valve and the removal of the pressure below; while if the spring is too strong the valve is returned with such force as to cause a harsh sound and rapid wearing. This necessitates more frequent renewals than if moved with a spring of the proper tension.

Inasmuch as the weight of the moving part of the valve is a factor in determining the required strength, and the diameter, pitch, temper, gauge of spring and material, determine the strength, it becomes practically impossible to lay down a rule for the selection of the proper spring for each condition. Experience shows that one can better determine what spring to use by the sense of feeling than by any rule or standard.

**Piston.** Having provided the inlet and outlet valves with proper opening and closing devices and made them capable of retaining the gas passing them, a piston for compressing the gas and discharging it from the compressor must be provided. For the vertical type of single-acting compressor in which both inlet valves are in the upper compressor head, the piston is best made as a ribbed disc with a hub at the center for the piston rod and a periphery of sufficient width to be grooved for the necessary snap rings. Three to five of these rings are generally used.

Fig. 12 illustrates the simplest form of piston of this type, A being the cast head, B the snap rings, and C the piston rod. The surface is faced square with the bore of the hub, and

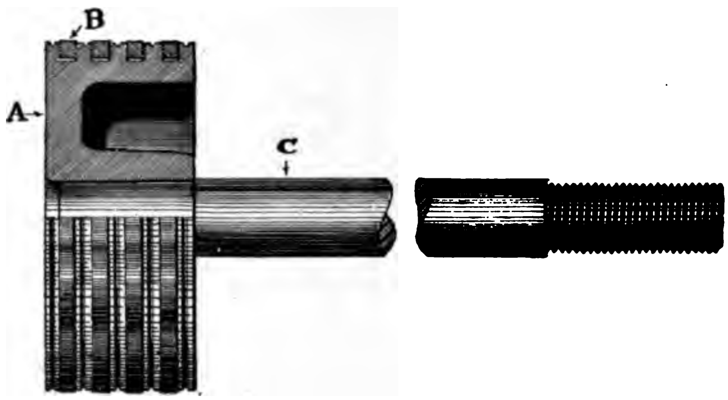



Fig. 12.

the rod forced in and riveted over, filling the small counterbore provided for this purpose. The cast head and rod having been previously roughed out, is now finished in its assembled condition, the rod made parallel and true to gauge, threaded to fit the crosshead and the grooves turned for the snap rings, which are made slightly larger than the bore of the compressor. A diagonal cut is made through one side and enough of the ring is cut out to allow it to slip into the cylinder without binding. It is then scraped on its sides until it fits accurately the groove in the piston. It is also well to turn a small half-round oil groove in the outer face of the piston between each ring which gathers and retains a portion of the oil used for lubrication, thus increasing the efficiency of the piston and collecting dust or scale and lessening the liability of cutting of the cylinder due to any of the usual causes.

The piston rod requires special care both in workmanship and material. In order to be effective it must be true from end to end and to be lasting under the variety of conditions which it operates, should be of a good grade of tool steel. The end which is usually made to screw into the crosshead is turned somewhat smaller, usually from $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter, than the portion passing through the packing or stuffing box principally to allow of returning or truing up the rod when it becomes worn, and also to allow it to pass through the stuffing box. After the rod is screwed into the crosshead it is secured and locked with a nut to prevent turning. The nut also allows the position of the piston to be changed to compensate for wear on the different parts of the machine by simply loosening the lock nut and turning the piston and rod in or out of the crosshead.

**The stuffing box** of the compressor, shown in Fig. 13, is one of the most difficult parts to keep in proper order. This is owing principally to one of two causes: not being in line with the crosshead guide or bore of the compressor, or the great difference of temperature to which it is subjected owing to the possible changes taking place in the evaporator. However, with the compressor crosshead guides, and stuffing box in perfect alignment, and a constant pressure or temperature on the evaporating side, it is a simple matter with almost any kind of packing on a machine of the vertical single-acting type to keep the stuffing box tight and in perfect condition. If, however, either of the above conditions are changed it becomes practically impossible to accomplish this. We have learned that perfectly constructed and operating valves is one of the essential features of a perfect machine. We also know that the alignment of the machine is equally important.

**Erection.** Experience in the building, erecting and operation of this class of machinery, shows that more machinery is condemned, more complaints made and difficulties encountered owing to these two points than all others put together. It is all important to the erecting and operating engineer that they be absolutely certain of these two points.

After the A frame, the compressor cylinder and its lower head have been placed in position, a fine hard line should be passed through the cylinder and stuffing box down through the guide and to the crank pin in the shaft, drawn tight and secured in some manner at each end and then callipered at each point. The different parts should be brought into perfect alignment before the rest of the machine is assembled.

Fig. 14 illustrates the methods of obtaining the proper

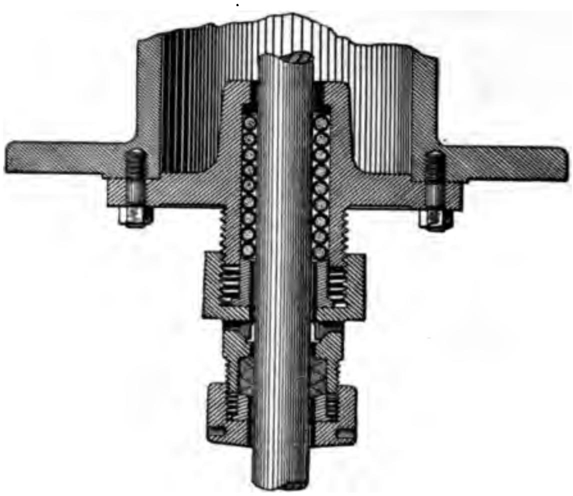


Fig. 13.

results. Assuming that the brasses are central with the connecting rod and the connecting rod with the crosshead, the line should of course be central with the crank pin and this condition should exist when the pin is at its top and bottom positions. In other words, when the line is placed midway between the collars on the crank pin when at the bottom stroke, and the shaft is revolved one-half revolution to its top stroke, the line should be exactly midway between them; or the top moved until such is the case, and this should be determined as absolutely correct before proceeding further. When this is accomplished we may proceed to the guides and caliper first at the bottom and then the top between the line and each side of the bore, moving the A frame by dressing the bottoms of the feet or packing under, as may be most desirable.

We may now examine the top of the compressor and the bottom of the stuffing box to determine whether or not these are central. By shimming or packing under the side of the compressor, the cylinder and the stuffing box may be moved in the

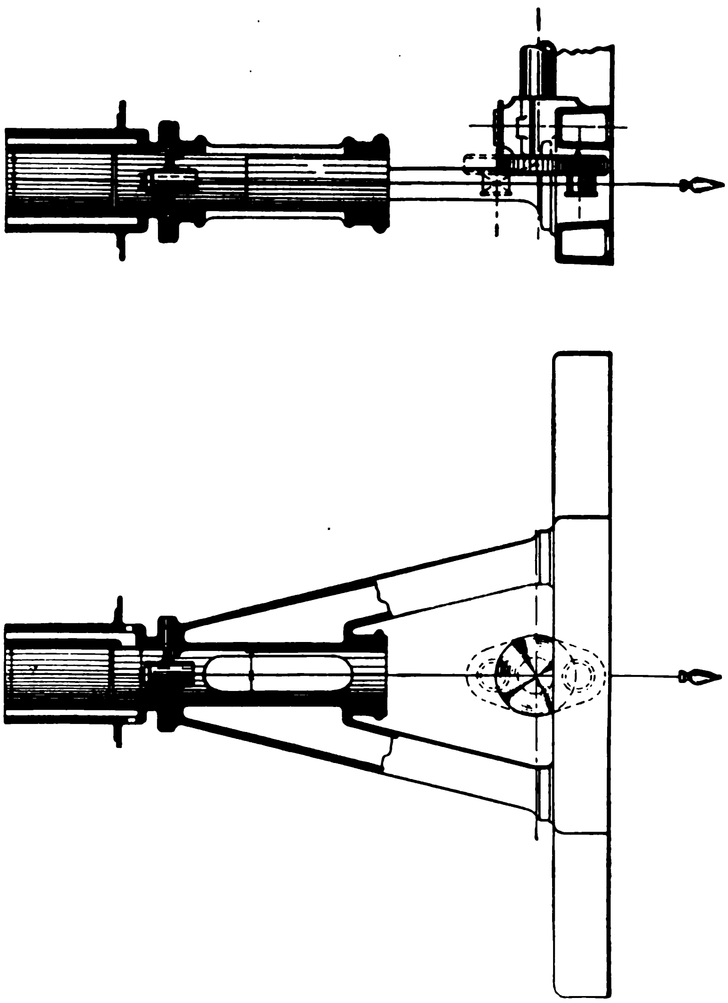
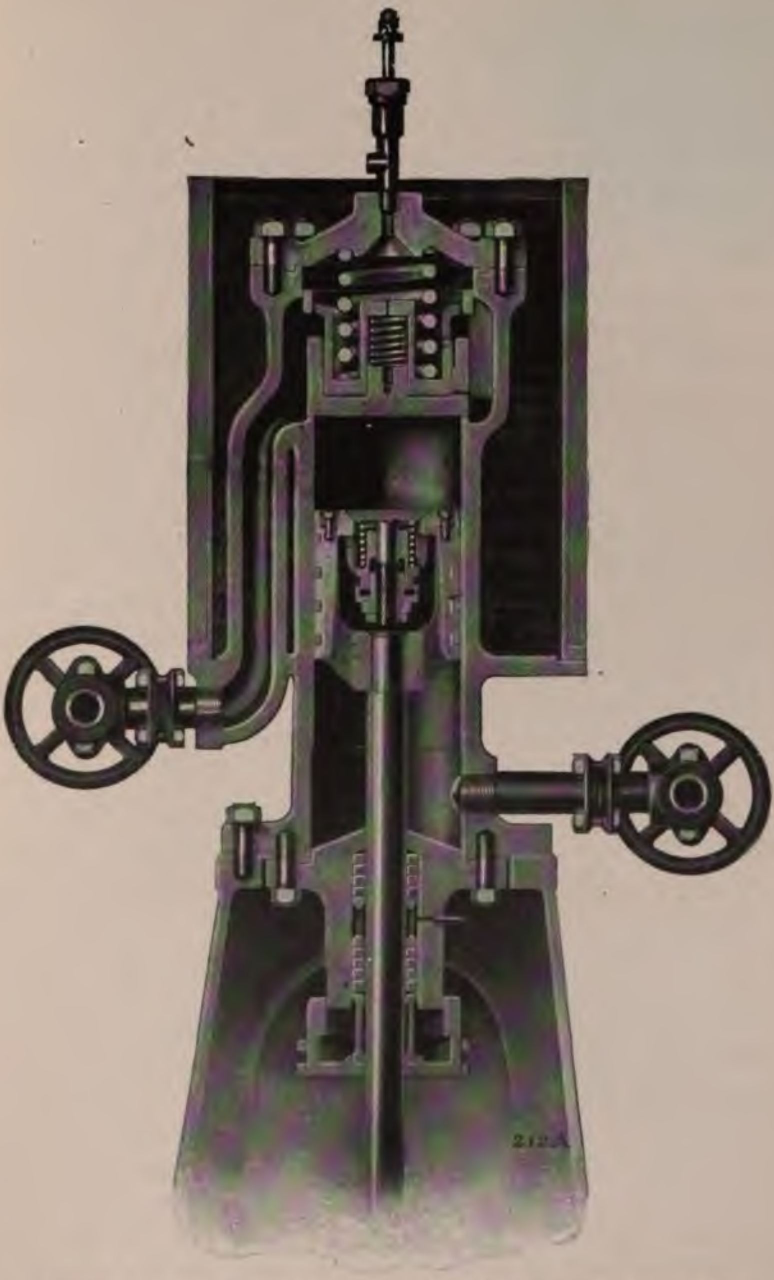


Fig. 14.

required direction; this will be found all that is necessary to correct the small inaccuracies. Of course, should objection be raised to the method, the other remedy is to dress the surfaces.

Having the different parts in proper alignment, we may now



Section of Frick Single Acting Gas Compressor Cylinder.

proceed with the assembling of the balance of the machine, feeling assured that with reasonably good workmanship and material, we will have a good running machine. It is well to have a compressor stuffing box of any of the several types in two parts or double packed (see Fig. 13), the inner to be of proper proportion to hold the packing against the loss of ammonia and the outer of only slight depth to retain the lubricating oil within the annular space provided between the two, and through which the rod passes in its travel. The packing may be drawn up or tightened by any one of several common devices, although a parallel device or one which causes the gland to move uniformly by tightening at one point is to be preferred. Although three or four separate bolts are very often used they are undesirable from the fact that they may cause a tipping or "cocking" due to the tightening or loosening of one.

There are innumerable materials for packing, and the "packing man" is encountered every day extolling the "good qualities" of his packing. It is probable that all have good points, but it is doubtful if any one make or kind would meet with the unqualified indorsement of all engineers; also no one packing is best for all conditions or duties. The condition and packing must be suited to one another; this will generally be accomplished by the good engineer.

In the construction of the stuffing box it is well to bush the bottom of the glands with Babbitt metal, because the rod is often pressed to one side crowding it against the side of the gland or bottom of box, causing the same to cut. When it becomes necessary to turn down the rod, a new bushing is all that is necessary to reduce the openings correspondingly.

**Water Jacket.** In the vertical single-acting type of compressor, it is usual to provide a water jacket, which may be cast in combination with the compressor cylinder or made of some sheet metal secured to an angle, which is bolted to a flange cast on the cylinder. It is usual to have this water jacket start at about the middle of the compressor (or a little below as shown in Fig. 15) and extend enough above to cover the compressor heads, valves and bonnets with water; the principal object of which is to keep these parts at a normal temperature and thereby improve the operation as well as protect the joints against the excessive heat which would be generated by the continued compression. It is also an advantage in the operation of the plant, since by reducing the temperature in the compressor and adjacent parts, the compressor is filled with gas of a greater density. It is also true that the heat extracted or taken up by the water at this point is a certain portion of the work performed in the condenser and therefore not a waste.

In the operation of the plant it is well to have plenty of water flow through the jackets, as the cooler the compressors are kept the better, but in plants in which water is scarce the quantity may be reduced correspondingly until the overflow is upwards of 100° Fahr. In extreme cases of shortage of water the overflow water from the ammonia condenser is sometimes used on the water jackets, that is, the entire amount of available water is delivered to the condenser, and a supply from the catch pan (if it be an atmospheric type) is taken for the water jackets, in which case a greater quantity may be used but at a higher temperature. It is customary to admit the water through the flange forming the bottom of the water jacket and overflow near the top into a stand pipe which is connected at its lower end through the flange to a system of pipes to take it away. To prevent condensation on the outer surface of the jacket, and to present a more pleasing appearance, it is frequently lagged with hardwood strips and bound with finished brass or nickel-plated bands. It is also well to have a washout connection from each jacket.

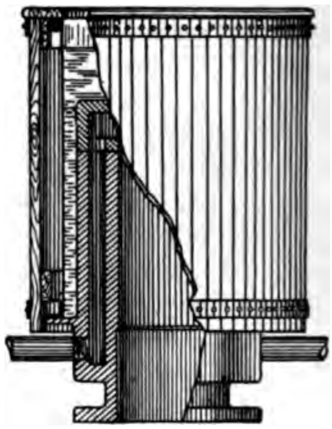


Fig. 15.

**Lubrication.** The vertical type of compressor requires the least amount of lubrication from the fact that all moving parts are in equilibrium. The slight amount of oil used is merely to keep the surfaces from becoming entirely dry. Excessive lubrication is an objection, owing to the insulating effect upon the surfaces of the condensing and evaporating system. Therefore it is well to feed to the compressors as little as is consistent with the operation of the machinery. A proper separating device should be located in the discharge pipe from the compressor to the condenser. To properly admit, or feed the lubricant to the compressors, sight feed lubricators should be provided, by which the amount may be determined and regulated. These may be of the

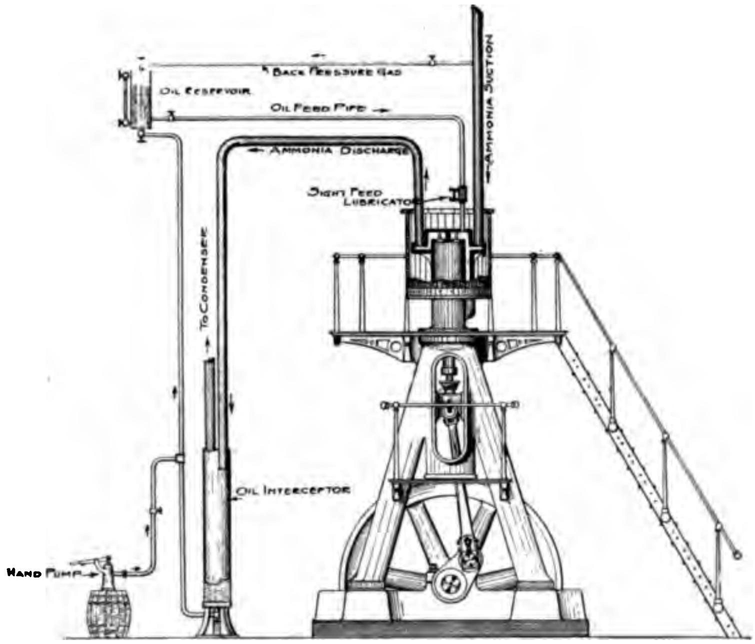



Fig. 16.

reservoir type, or better still the droppers, fed from a large reservoir through a pipe and which may be filled by a hand pump when necessary (see Fig. 16). Owing to the action of ammonia on animal or vegetable oils, other than these must be used as a lubricant for the compressor. The principal oil for this purpose (and when obtained pure, a very good one) is the West Virginia Natural Lubricating Oil or Mount Farm, which is a dark-colored oil not affected by the action of the ammonia or the low temperature of the evaporator. Of late years the oil refining companies have put on the market a light-colored oil which appears to give good results for the purpose. Care should be used, however, in the selection and oil should not be used unless it is of the proper grade, as serious results follow the use of inferior oils. The usual result is the gumming of the compressors and valves or the saponifying under the action of the ammonia through the system.

## LOSSES.

Having described the compressor and its parts, let us take up the losses due to the improper working or assembling of the parts of the machine, before proceeding with the description of the rest of the plant. As has been stated in a general way, the economy of the compressor lies in its filling at the nearest possible point to the evaporating pressure and then compressing and discharging at the lowest possible pressure, as much of the entire contents of the cylinder as possible. If the compressor piston does not travel close to the upper end (of a single-acting machine) or the machine has excessive clearance, the compressed gas remaining in the cylinder re-expands on the downward stroke of the piston and gas from the evaporator will not be taken into the compressor until the pressure falls to, or slightly below, this point, and the loss due to this fault is equal to the quantity of gas thus prevented from entering the compressor plus the friction of the machine while compressing the portion of the gas thus expanding.

If we make a full discharge of the gas and there is a leaky outlet valve in the compressor, the escape and re-expansion into the compressor affects not only the intake of the gas at the beginning of the return stroke, but continues to affect the amount of incoming gas during the entire stroke and the capacity of the machine will be correspondingly reduced. If the inlet valve is leaky or a particle of scale or dirt becomes lodged on its seat, as the piston moves upward the portion of the gas which may escape during the period of compression is forced back to the evaporator and a corresponding loss is the result. A piston which does not fit the compressor, faulty piston rings, or a compressor which has become cut or worn to the point of allowing the escape of gas between the cylinder and piston has the same effect as the ill conditioned suction valve. The loss due to leaky or defective cylinders, joints or stuffing boxes, are not included under this head as these more generally effect the loss of the material than the efficiency of the compressor.

To present graphically the losses due to the above causes refer to Fig. 17, which illustrates the usual indicator card taken from an ammonia compressor and the effect upon it of the various losses.

The different mechanisms employed in actuating the compressor piston, such as crossheads, connecting rods, pins, crank shaft and bearings, are of usual engine practice. A detailed description will not be given here. It should be stated that owing to the steady load and the continuous service usually demanded of

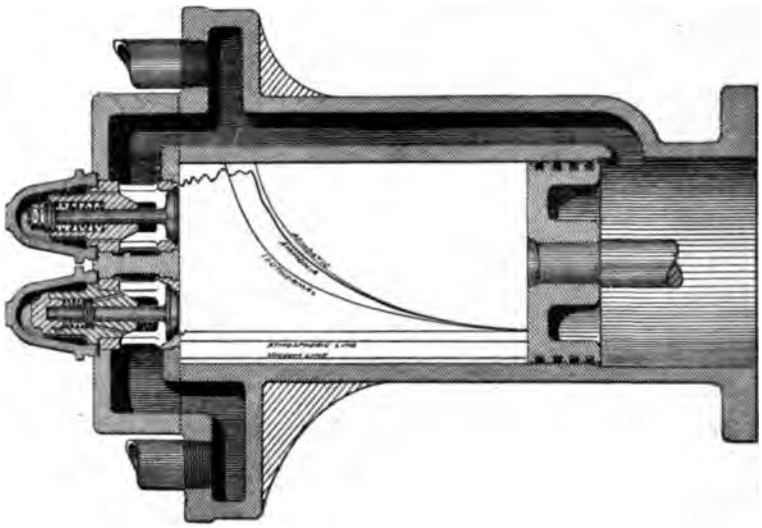


Fig. 17.

a refrigerating plant, and the occasional high pressures encountered in the extremely warm weather, the construction should be of the best and the wearing surfaces ample to withstand the hard service. The many types of machines and the methods of connecting the power or engine are of almost endless variety. It is sufficient to state that the general classes of engines are of vertical or horizontal single-cylinder, tandem or cross compound, condensing or non-condensing.

The horizontal double-acting compressor embodies all the general principles of the vertical single-acting, but having certain modifications to meet the mechanical differences presented. They may be divided into two classes, those having water jackets and those without. The former usually has a water jacket extending about the body of the cylinder but not over the heads and valves as in the single-acting compressor. Compressors not provided with water jackets are internally cooled either by evaporation of a portion of the ammonia, or the injection of ammonia or cooled oil. The claims of both these last named systems are that instead of the curve of compression being close to the adiabatic it is brought nearly to the isothermal, and that a corresponding economy in horse power required to operate the machine is effected. Owing to the fact that this type of compressor takes in and discharges gas in both directions, it is necessary that inlet and outlet valves be provided in both heads, and that the inner head be provided with a stuffing box also for the piston rod. This renders it impossible to place the valves horizontally, and as a result, the valves are placed at an angle of from 30° to 45° from the center of the compressor, and the inner face of the heads and pistons made on an angle to conform to this; or sometimes the valves are spherical, to avoid clearance which would result from the difference in their surfaces. The weight of the piston and rod being towards the bottom of the cylinder, it is necessary that the piston be of considerable length to provide a greater surface for wear.

The stuffing box must have sufficient depth to successfully retain the gas during the period of compression, and lubrication should take place while the rod is passing through the packing. This is accomplished with a small oil pump actuated from the moving parts of the machine or a pressure system regulated by the pressure in the oil separator. In each case oil passes between the double packing thereby causing the piston rod to pass through a chamber of oil.

The compressor valves and their cages are of the description already given and the same care and caution regarding the construction and operation apply to the valves of this type of machine, but the fact that they are horizontal or nearly so makes their construction somewhat different and necessitates springs of different strength. The valves, cages and springs are covered by a dome bolted in place and its union with the compressor head is provided with a gasket to prevent loss of ammonia. It is well to have at hand duplicates of the compressor valves and springs, as an entire valve can be changed in less time than it takes to repair one out of order. As the machine during this time must remain out of service, it is customary for the builders to supply these in duplicate. After a valve is taken out and replaced, it is well to have the faulty one put in perfect condition, the strength of springs tested, the seat and stem corrected, oiled and put away in readiness to be used again when the occasion requires.

This type of compressor is usually driven from a rotating shaft with the ordinary connecting rod by a crank and crosshead. Adjustment for wear is provided in the piston rod at the cross-head, and the position of the piston may be adjusted between the heads of the compressor by screwing in or out of the crosshead. The clearance of the compressor piston is important; it should be as small as possible and yet not allow the piston to strike the heads. This naturally cannot be reduced to the small degree possible in the single-acting type, from the fact that it must be adjusted to both heads, and the expansion and contraction of the piston and connecting rod and wear is of such an amount as to render a close adjustment impossible. Fig. 18 is a sectional cut of a modern type of double-acting compressor with water jacket; Fig. 4 a section of one not using the water jacket and Fig. 10 an elevation of either in combination with its motive power, a Corliss engine, shaft, fly wheel, etc.

The stuffing-box oil pump is shown in Fig. 16 which illustrates the general method of lubricating the compressor piston, the oil being pumped through the box and returning to a catch pan or basin provided in the bed plate.

## THE AMMONIA CONDENSER.

The Ammonia Condenser, or liquefier, as briefly stated in the description of the system, is that portion of the plant in which the gas from the evaporator, having been compressed to a certain point, is cooled by water and thereby deprived of the heat which it took up during evaporation; consequently it is reduced to its initial state, that is, liquid anhydrous ammonia. Let us consider the general principles governing the action before describing the types. On account of the duty having been performed, the ammonia as it leaves the evaporator is a gas of low temperature,

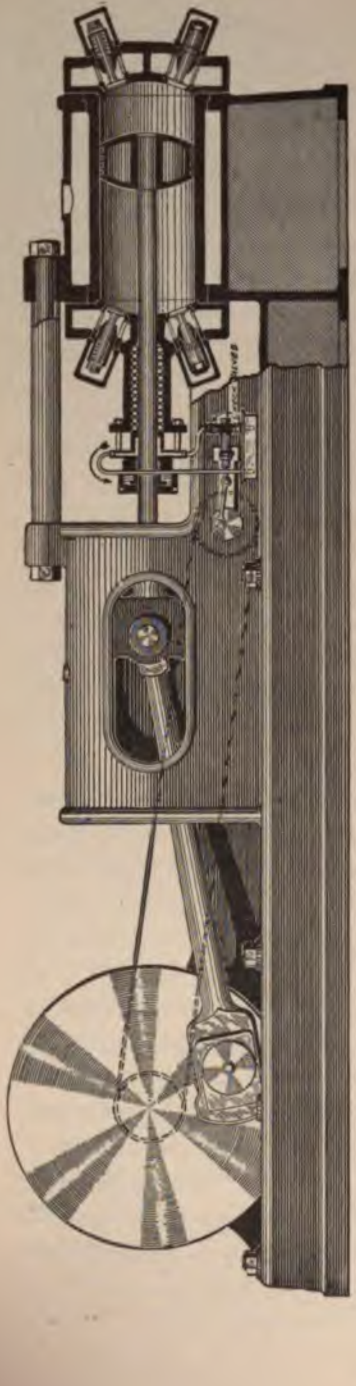


Fig. 18.

usually 5° to 10° below that of the brine, or other body upon which it has been doing duty, yet it is laden with a certain amount of heat, although at a temperature not ordinarily expressed by that term. It is a well-known fact that we cannot obtain a refrigerating agent which can absorb heat from a body colder than itself, and it is therefore necessary to bring the temperature of the ammonia gas to a point at which the flow of heat from the one to the other will take place. This is done by withdrawing part of the heat in the ammonia in the following manner: The cold gas is compressed until its pressure reaches such a point that at ordinary temperatures it will condense to liquid form. As it leaves the compressor it is very hot because of the fact that it still contains nearly all of the heat it had when it left the evaporator in only a small portion of the space occupied before. Thus when it reaches the condenser it is much warmer than the cooling water and will readily give up its heat to the cold water—so much that its latent heat is absorbed by the water and it condenses into anhydrous ammonia.

The temperature of water if pumped from surface streams will average about 60° F and since we cannot expect to get the ammonia any colder than this it must be compressed until the boiling point corresponding to the pressure obtained is at about 75° F.

In the table, page 83, we find that this temperature corresponds to a pressure of 144.25 pounds per square inch (absolute) or 126.55 pounds per square inch (gauge).

Thus if the gas is compressed until the gauge reads 126.55 and then passed into a condenser where the temperature of the water is less than 75° F the water will absorb the latent heat and we have accomplished our object which was to remove some of the heat contained in the ammonia. In this condition it is drained from the condenser into the ammonia receiver to again repeat the cycle of operation.

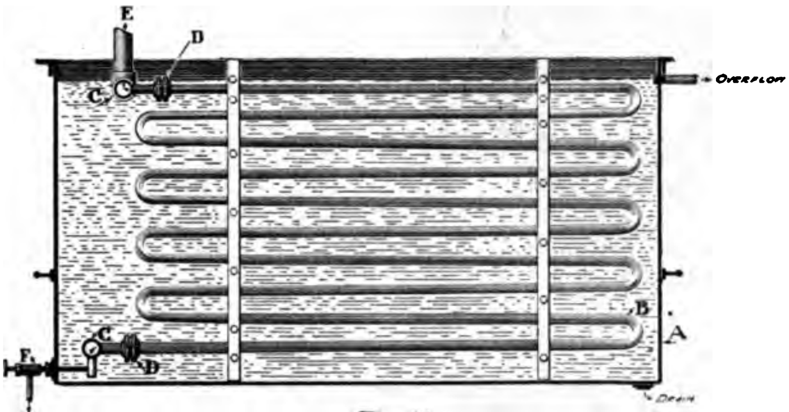



Fig. 19.

The forms of condenser may be divided into three classes; the submerged, atmospheric, and double-pipe. Of each of these classes a number of different types and constructions are in use. To illustrate the general principles, however, it is only necessary to present one of each type.

**The Submerged Condenser** consists of a round or rectangular tank with a series of spiral or flat coils within joined to headers at top and bottom with proper ammonia unions. In Fig. 19 is shown a sectional elevation of a popular type of submerged condenser. A wrought iron or steel tank A is formed by plates from $\frac{3}{16}$ to $\frac{5}{16}$ inch thick, of the necessary dimensions to contain the coils, and sufficiently braced around the top and sides to prevent bulging when filled with water. A series of welded zigzag pipe coils B are placed in the tank and joined to headers C with ammonia unions D. The ammonia gas enters the top header through the pipe E and an outlet for the liquefied ammonia is provided at F with a proper stop valve. Water is discharged or admitted to the tank at or near the bottom and overflows at outlet

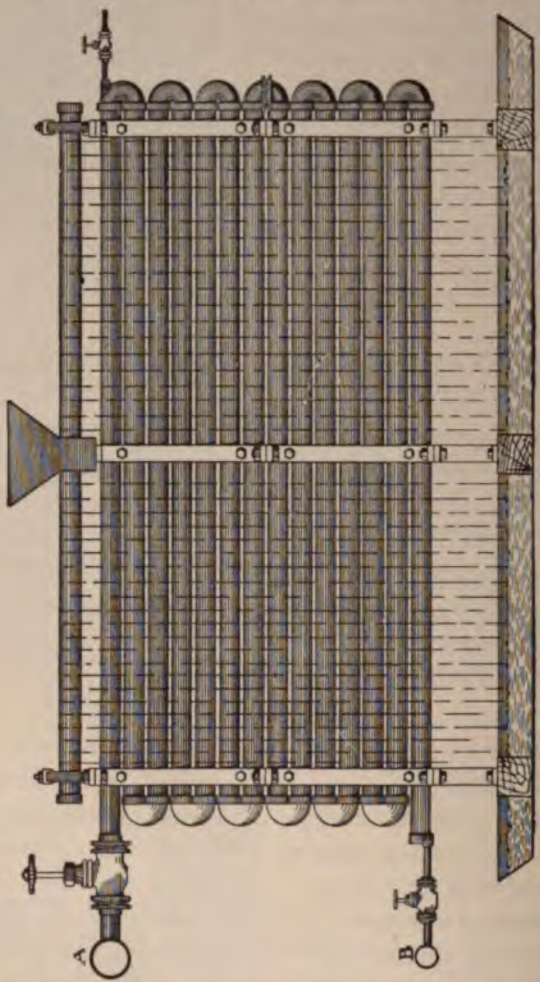



Fig. 20.

M. It will be seen that in this type of condenser a complete reverse flow of the current is effected, the gas entering at the top and the liquid leaving at the bottom, while the water enters at the bottom and leaves at the top, thereby bringing the coldest water in contact with the coolest gas and the warmer water in contact with the incoming or discharged gas from the compressor, thereby presenting the ideal condition for properly condensing ammonia.

Owing to the necessarily large spaces between the coils and the distance between the bent pipes, the portion of water coming in contact with the surface of the pipes must be small compared with the total amount passing through; it is, therefore, uneconomical as regards amount of water used. With water containing a large amount of floating impurities the deposit on the coils is considerable, and not easily removed owing to the limited space between the coils, and furthermore, the dimensions of the tank necessary to contain the requisite amount of pipe for a plant of considerable size is so great and its weight when equipped with coils and filled with water requires such a strong support that its use is now limited to certain requirements and localities.

A better shape for a condenser of this type is one of considerable height or depth, rather than low and broad. This is owing to the fact that the greater the length of travel of the water and gas in opposite directions, the greater the economy. The number of coils used should be such that the combined internal area of the pipes equals, or exceeds the area of the discharge pipe from the compressor. The circular submerged condenser is similar to the above described except that the tank is circular and the coils bent spirally.

**The Atmospheric** type of condenser most generally used is made of straight lengths of 2-inch extra-strong, or special pipe, usually 20 feet long, screwed, or screwed and soldered into steel return bends about 3½-inch centers and usually from eighteen to twenty-four pipes high. The coil is supported on cast or wrought iron stands and placed within a catch pan, or on a water-tight floor, having a proper waste water outlet and supplied with one of the several means of supplying the cooling water over their surfaces. Stop valves, manifolds and unions connect with the discharge of the compressor and the liquid ammonia supply to the receiver.

In the manner of making the connections to this type of condenser and the taking away of the liquefied ammonia as well as in the devices for supplying the cooling water, a great variety exists; Fig. 20 represents a side elevation of an ammonia condenser with the discharge or inlet of the gas from the compressor entering at the top A and the liquid ammonia taken off at the bottom B while the water is supplied over the coils flowing down into the

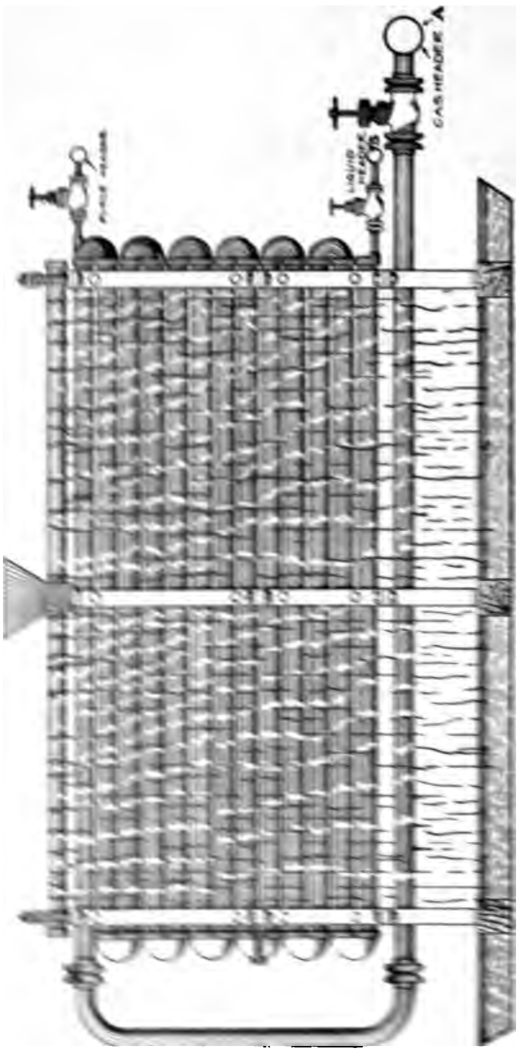



Fig. 21.

[illegible]

ammonia. The temperature governing or determining the point of condensation will be that of leaving the condenser, or at the bottom pipe in which the liquid ammonia is withdrawn. Owing to this arrangement it is not favorable to a low condensing pressure or economy in the water used. Fig. 21 represents a type in which an attempt is made to eliminate this undesirable feature, and in which it is expected to use the waste from the condenser proper, in taking out the greater part of the sensible heat from the gas leaving the compressor.

The construction of this condenser is identical with that shown in the preceding figure except that its uppermost pipe is continued down and under the pipes forming the condenser proper; it passes backward and forward in order that a large proportion of the heat may be removed by the water from the condenser proper, before the ammonia enters the condenser. A supplemental header is sometimes introduced in connection with this pipe for removing any condensation taking place in it.

A third type of this condenser is shown in Fig. 22. In this type a reverse flow of the gas and water takes place. The gas enters the condenser through a manifold or header A at the bottom and continues its flow upward through the pipes to the top; at several points drain pipes are provided for taking off the condensation into the header B. The condensing water flows downward over the pipes. The form is the most nearly perfect condenser of the class.

The atmospheric type is a favorite, and possesses many features that make it preferred to the submerged. Its weight is a minimum, being only that of pipe and supports and a small amount of water. The sections or banks may be placed a favorable distance apart to facilitate cleaning and repairs, while the atmospheric effect in evaporating a portion of the condensing water during its flow over the condenser, thereby obtaining the advantage of its latent heat as well as the natural raise in its temperature, adds materially to its efficiency.

The various devices for distributing the water over the condenser are numerous:

Fig. 23 represents the simplest and most easily obtained; a simple trough with perforations at the bottom for allowing the water to drip through to the condenser.

Fig. 24 is a modification of the one shown in Fig. 23. This is intended to prevent the clogging of the perforations, by allowing the water to flow into the space at one side of the partition, and then through a series of perforations into the second, and

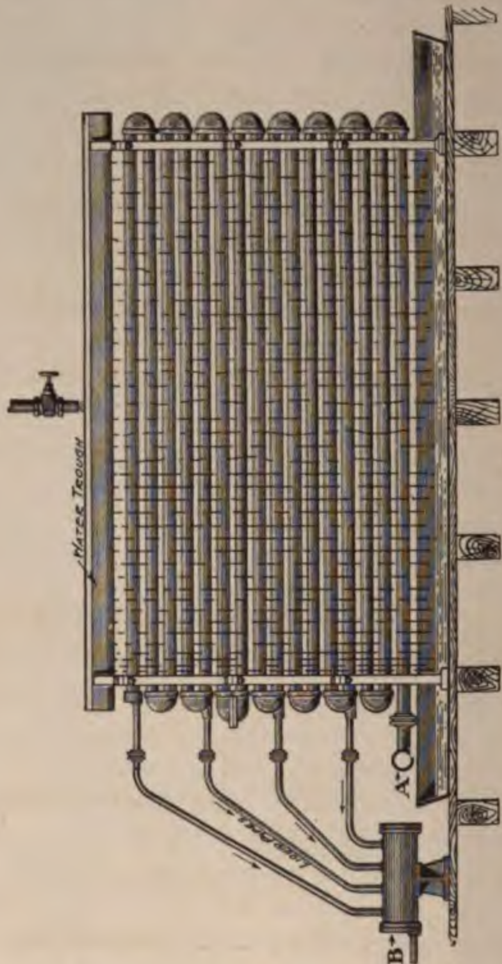



Fig. 22.

thence through a second set of perforations in the bottom to the pipes in the condenser.

Fig. 25 is a type of trough, or water distributor, designed to overcome the objections to a perforated form of trough, and the consequent difficulties due to the clogging or filling of the perforations. As will be readily understood from the illustration, this is also made of galvanized sheet metal with one side enough higher

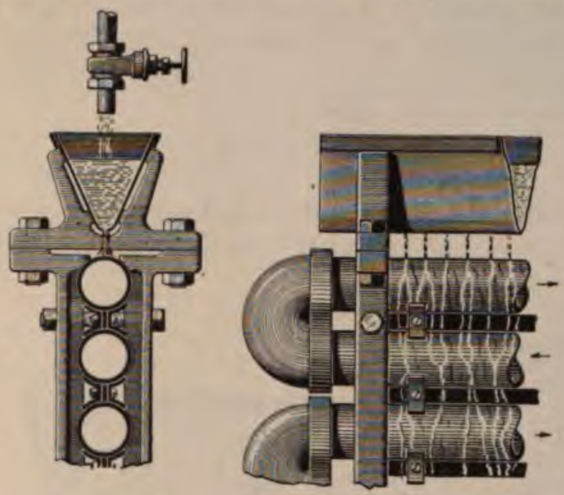


Fig. 23.

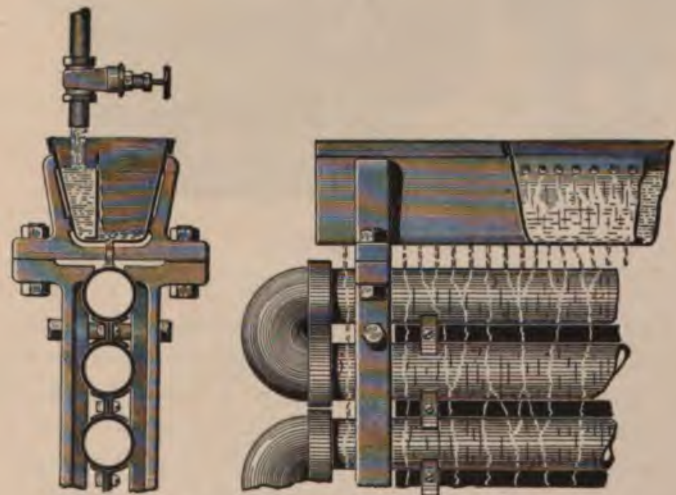


Fig. 24.

than the other to cause the water to overflow through the V-shaped notches or openings along the top of the straight or vertical side of the trough, and down and off the serrated bottom edge to the pipes.

The object of the serrated edges, as will be apparent, is the more even distribution of the water, owing to the fact that while it would be practically impossible to obtain a uniform flow of water over a straight and even edge of a trough, particularly if the amount is limited, it is an easy matter to regulate the flow through the V-shaped openings.

Fig. 26 is termed the "slotted water pipe." It is a pipe slotted between its two ends, from which the water overflows to the series of pipes below. It is good practice to lead the water supply to a cast-iron box at the center of the condenser, into the

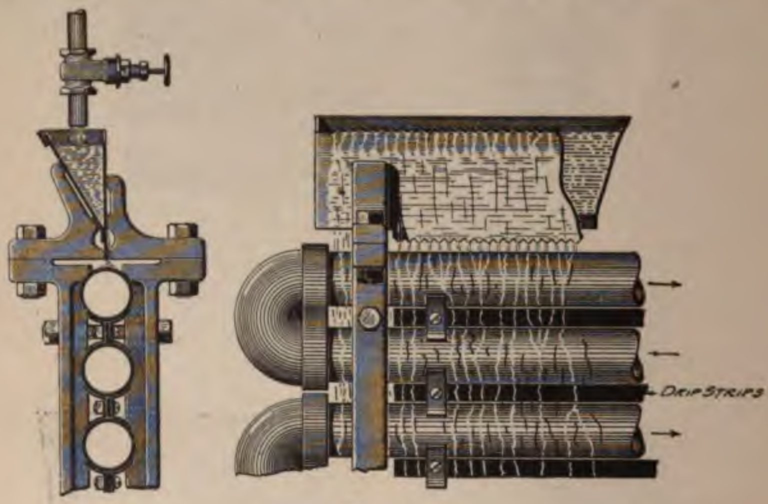
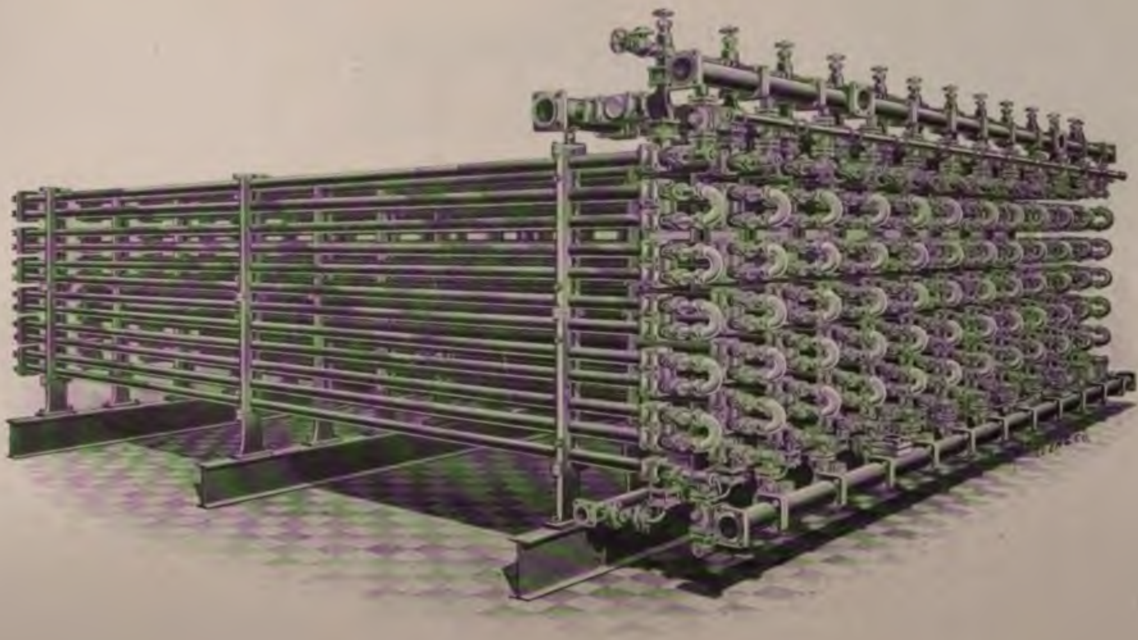



Fig. 25.

sides of which is screwed a piece of pipe (usually 2-inch) reaching the ends of the condenser, and having its outer ends capped, which may be removed while a scraper is passed through the slot from the center towards the ends while the water is still flowing, thereby carrying off any deposit within the pipe. This forms a very durable construction, and not liable, as with the galvanized drip trough, to disarrangement or bending out of shape due to various causes. It is impossible, however, to obtain the uniform flow of water over the condenser with this, as with the serrated or perforated troughs, particularly if the supply is limited, from the fact as stated in describing the overflow trough, viz: the impossibility of obtaining a sufficiently thin stream of that length.



DOUBLE-PIPE AMMONIA CONDENSER.
The Fred W. Wolf Company.

**The Double-Pipe Condenser** is a modern adaptation of an old idea, given up owing to its complex construction and the imperfect facilities available for its manufacture. Also, like the Brine Cooler, it has come into use with great rapidity, and has brought forth many novel ideas of principle and construction. It combines the good features of the atmospheric as well as the submerged; as in the former the weight is small and it is accessible for repairs. It has the downward flow of the ammonia and upward flow of the water, effecting a complete counter flow of the two, minimizing the amount of water required and taking up the

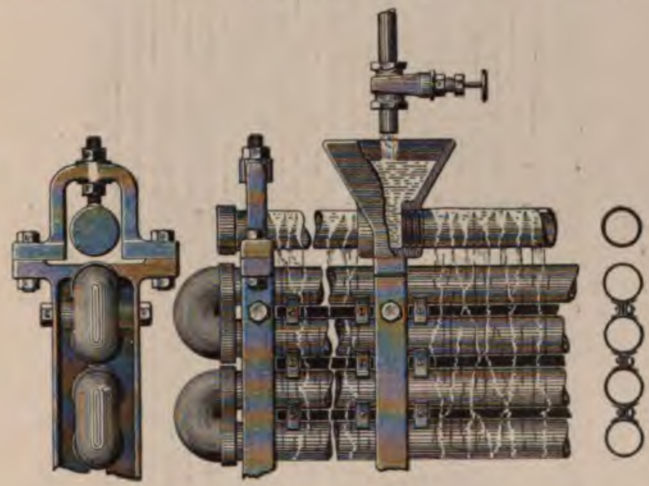


Fig. 26.

heat of condensation with the least possible difference between the ammonia and water.

The two general forms of construction are a combination of a $1\frac{1}{4}$-inch pipe within a 2-inch pipe, or a 2-inch pipe within a 3-inch. The water passes upward through the inner pipe, while the gas is discharged downward through the annular space; or, the position of the two may be reversed, the ammonia being within the inside pipe while the water travels upward through the annular space. They are also constructed in series, in which the gas enters a number of pipes of a section at one time, flowing through these to the opposite end to a header or manifold, at which point the number of pipes is reduced, and so on to the

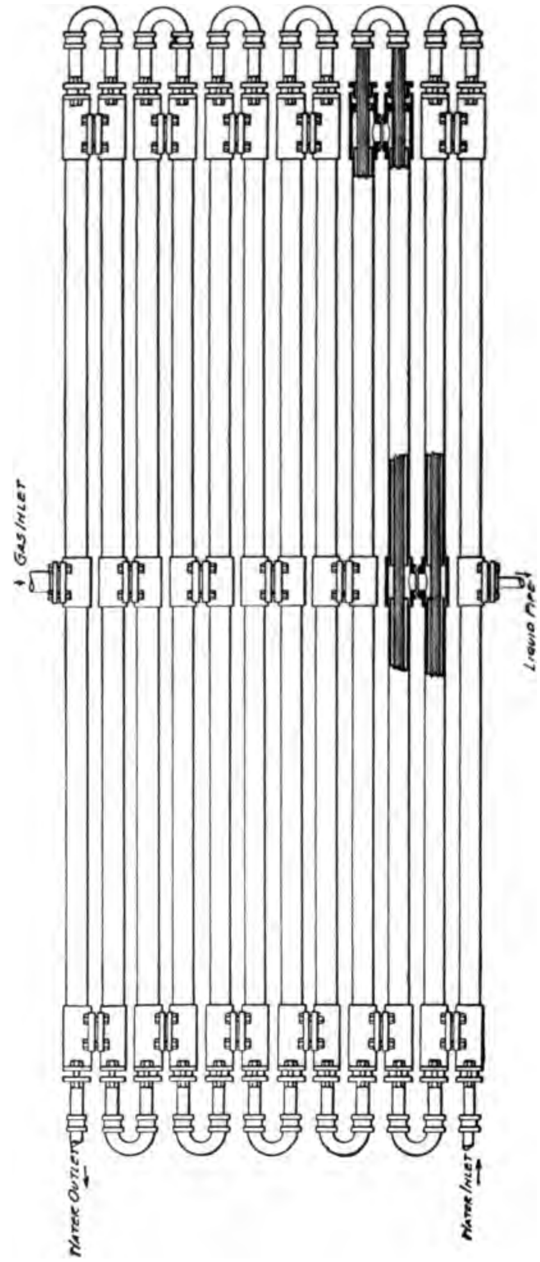



Fig. 27.

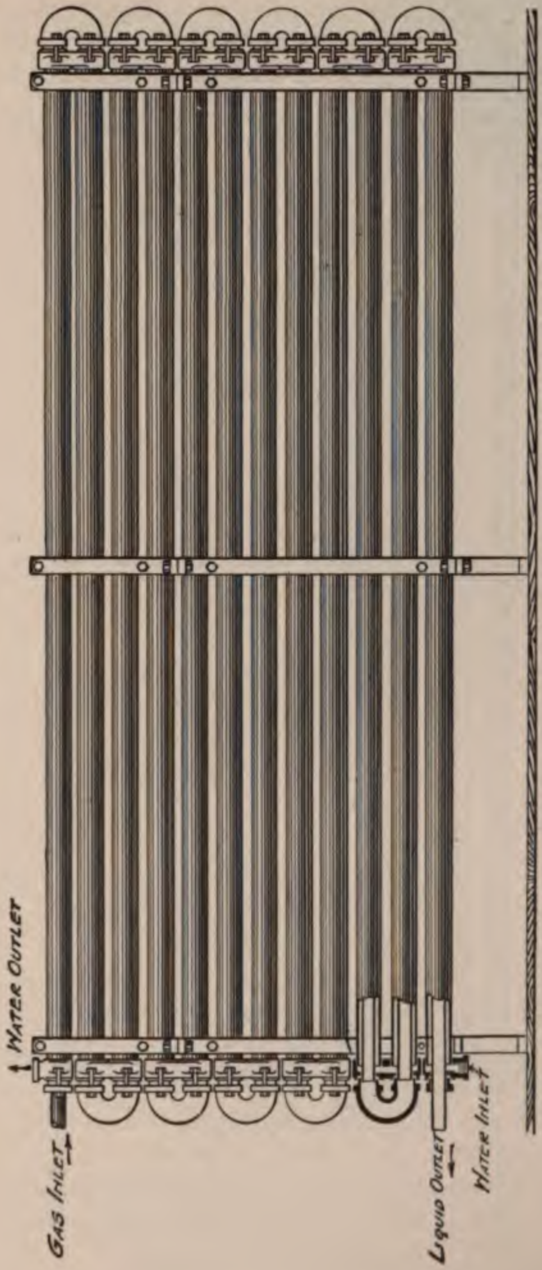



Fig. 28.

bottom with a constantly reduced area. The theory of this construction being that the volume of the gas is constantly reduced as it is being condensed.

Figs. 27, 28 and 29 illustrate a general range of the various types in use.

It is usual in the construction of this type to make each section or bank twelve pipes high by about 17½ feet long; they are rated nominally at ten tons refrigerating capacity each, although for uneven units the construction is made to vary from 10 to 14 pipes in each.

**The Oil Separator or Interceptor** is a device, or form of trap, placed on the line of the discharge between the compressor and the condenser to separate the oil from the ammonia gas. It is to prevent the pipe surface of the condensing and evaporating system from becoming covered with oil which acts as an insulator and prevents rapid transmission of heat through the walls.

The construction admits of quite a variety of principle, from the plain cylindrical shell with an inlet at one side or end and an outlet at the other, to the almost endless variety of baffle plates, spiral conductors and reverse-current devices. The object is similar to that of the steam or exhaust separator, and generally speaking, that which would be effective in one service would be so in the other. Figs. 30, 31 and 32 illustrate three of the most common types in use; from these the student will understand the general principles.

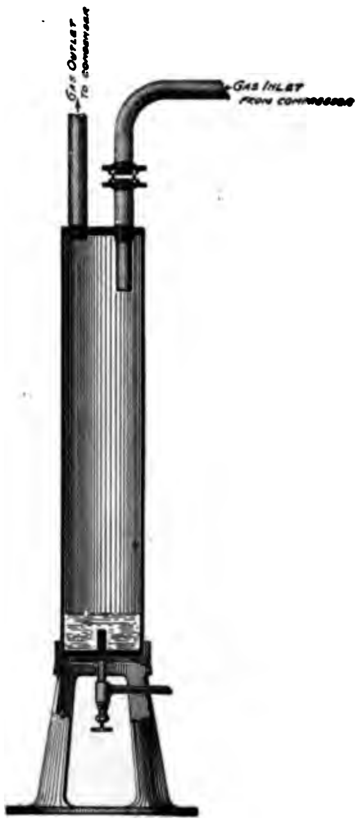



Fig. 30.

## AMMONIA RECEIVER.

The Ammonia Receiver or Storage Tank is a cylindrical shell with heads bolted or screwed on, or welded in each end, and provided with the necessary openings for the inlet and outlet of the ammonia, purge-valve and gauge fittings. They may be vertical or horizontal; the former type is generally used on account of the saving of floor space, while the horizontal is necessary when the condenser is located so low as to make the flow of the liquid ammonia into the vertical type impossible. A convenient location for the receiver in a plant in which the condenser is located above the machine room, is against the wall, or at one side of the room on a bracket or stand at one side of the oil interceptor, the sizes of the two being generally the same. They are then more readily under the control of the engineer than if at some out of the way place.

Fig. 31.

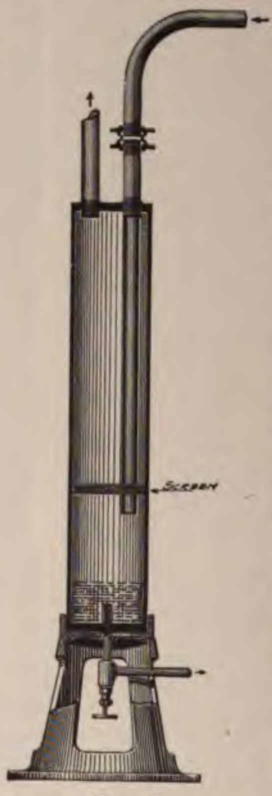


Fig. 32.

Fig. 33 illustrates a receiver of the vertical type with the usual valves and connections for the proper equipment. The liquid ammonia enters at the top and is fed to the evaporator from the side near the bottom, the space below this opening being provided for the accumulation of scale, dirt, or oil, and means are provided for drawing off through the purge valve in the bottom.

### PIPES, VALVES AND FITTINGS.

**Pipes.** Extra strong, or extra heavy pipe (so called) is the generally accepted pipe for connecting the various parts of the refrigerating system. Wrought-iron pipe is generally preferred to steel. Frequently, however, and particularly for the evaporating or low-pressure side of the system, a special weight or grade of pipe is used, also standard or common pipe is sometimes employed for this purpose. Without knowing the particular conditions under which this is to be used, or the relative value of the material, or manner in which the pipe is made, it is always better to use and insist on having the standard extra-strong grade. The threads should be carefully cut, with a good sharp die, making sure that the top and bottom of the threads are sharp and true. With this precaution, and an equally good thread in the fitting, it is not difficult to form a good and lasting joint. Particular care should also be taken that the pipe screws into the fitting the proper distance, and forms a contact the entire length, rather than to screw up against a shoulder without a perfect fit in the thread. This latter often causes leaky joints sometime after the plant has been operated; the temporary joint formed by screwing in too deep against the shoulder or ill-fitting threads very often passes the test and is used for some time after until the combined effect of heat and cold, and action of the ammonia cause it to break out. It is a safe rule that no amount of solder or other doctoring that is not backed up by a good fitting thread to support it can make an ammonia joint. This is particularly true of the discharge or compression side of the plant.

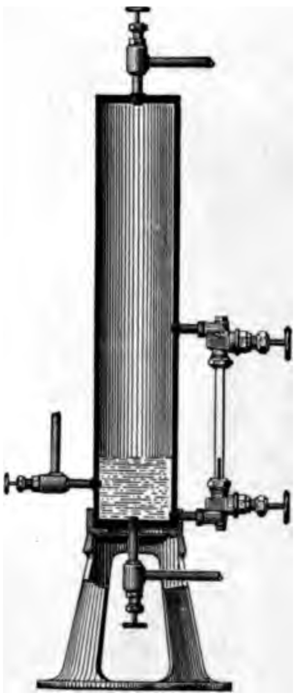


Fig. 33.

The manner of making these joints, may be divided into those having a compressible gasket between the thread on the pipe and the fitting into which it screws and the screwed joint formed by a threaded pipe screwed into a tapped flange or fitting. The latter may be divided into those having a soldered joint, or one in which the union is formed by the threads only, with some of the usual cements to assist in making a tight joint.

The two most prominent types of gasket fittings are shown in Fig. 34 and 35. The former is known in this country as the Boyle Union, and is extensively used. As will be observed, the drawing together of the two glands by the bolts, compresses the gaskets, (usually rubber) against the threaded sides of the pipe, the bottom and sides of the recess in the flanges, and the edges of the ferrule between the two gaskets.

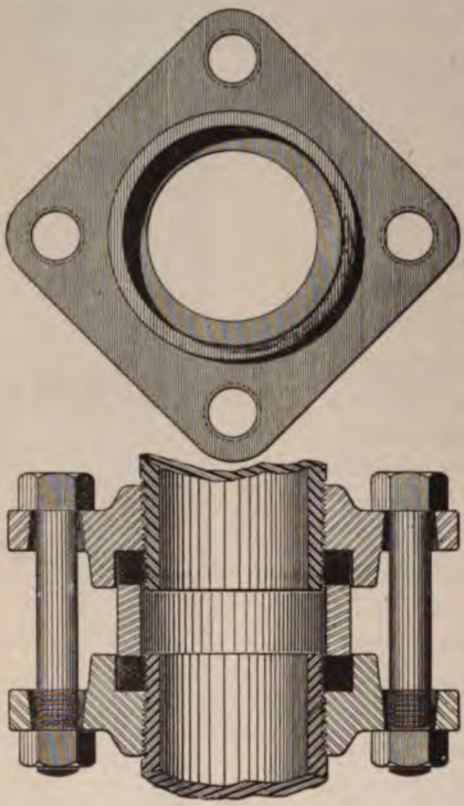


Fig. 34.

Fig. 35 represents a union or joint quite frequently used, although not as commonly as the former. In this the pipe is threaded and screwed into the body of the fitting, but not to form an ammonia-tight joint; leakage is prevented by a packing ring compressed by the gland against the pipe thread and the walls of the recess.

In Fig. 36 (a type of ammonia coupling), the contact between the pipe and fitting is made to withstand the leakage of the gas without the aid of packing or other material other than solder or some of the usual cements; the two flanges are bolted together with a tongue and grooved joint having a soft metal gasket. This makes a permanent and durable fitting.

Other fittings of the class, as ells, tees, and return bends, are usually provided with one of the above methods of connecting with the system, and the different types described may be obtained of the builders of refrigerating machines.

**Valves** for the ammonia system of a refrigerating plant are of special make and construction, being of steel or semi-steel, with a soft metal seat which may be renewed when worn, and metal gaskets between the bonnets and flanges.

The usual types are Globe, Angle and Gate, subdivided into screwed and flanged. Fig. 37 is a generally adopted type of the flanged globe ammonia valve, while Fig. 38 represents the angle valve of the same construction. This seems to represent the best elements of a durable and efficient valve.

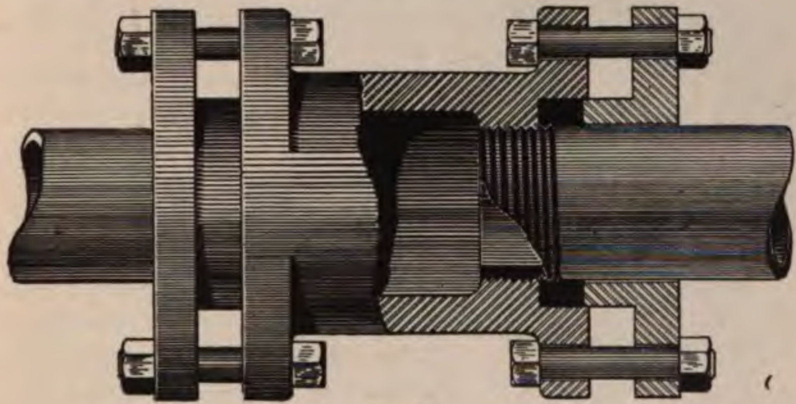


Fig. 35.

For a valve or cock requiring a fine adjustment as is frequently the case in direct-expansion systems, particularly where the length of the evaporating coil or system is short, a V-shaped opening is desirable. Fig. 39 represents a cock for this purpose which will be found to be effective and meet the most exacting requirements.

**Pressure Gauges.** Two gauges are necessary for an ammonia plant of a single system; one to indicate the discharge or condensing pressure, and one for the evaporator or return gas pressure to the compressors.

Owing to the action of ammonia on brass and copper the gauges for this purpose differ from the ordinary pressure gauge in that it is made with a tube and connections of steel instead of brass, and this construction is the general choice of gauge makers; in other respects the construction is similar. For machines of small capacity instruments with 6-inch dials are common, while for larger plants 8-inch is the generally adopted size. The graduation for the high pressure gauge is usually to 300 pounds pressure, and if a compound gauge is used, it is made to read to a vacuum also. This latter is only needed on certain occasions and frequently omitted from the high-pressure gauge. Owing to the necessity of removing the contents of the system at certain times and usually through the evaporating side of the plant, the gauge for this portion of the system is graduated to read from a vacuum to 120 pounds pressure.

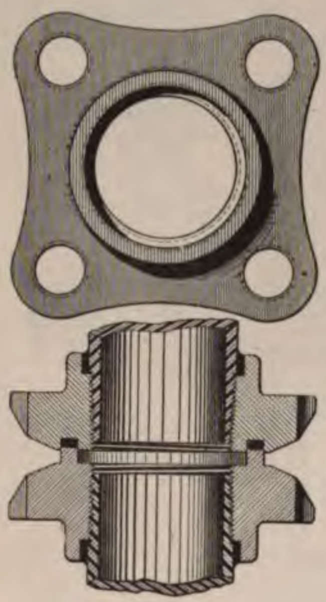


Fig. 36.

In connecting the gauges to the system, it is customary to locate the opening in the discharge and return gas lines near the machine within the engine room, placing a stop valve at some convenient point and carrying a line of $\frac{1}{4}$ or $\frac{1}{2}$ inch extra strong pipe to the gauges, making the joints with the usual ammonia unions. On account of the possibility of leakage of ammonia gas from the gauge tube, it is often considered advisable to fill the gauge pipe with oil (of the kind used for lubricating the ammonia compressor) for a short distance above the gauges, upon which the pressure of the gas will act, causing the gauge to move properly but without allowing the ammonia gas to enter the gauge. This is an application of the same principle as the steam syphon or bent-pipe arrangement in use with steam gauges, for the purpose of keeping the heat and action of steam from the gauge mechanism by the retaining of water in the gauge connection.

Other gauges used about the refrigerating plant are of the ordinary pressure or vacuum types and do not need a special description, as their construction and manner of applying to the different parts of the system are well known to the engineer. It

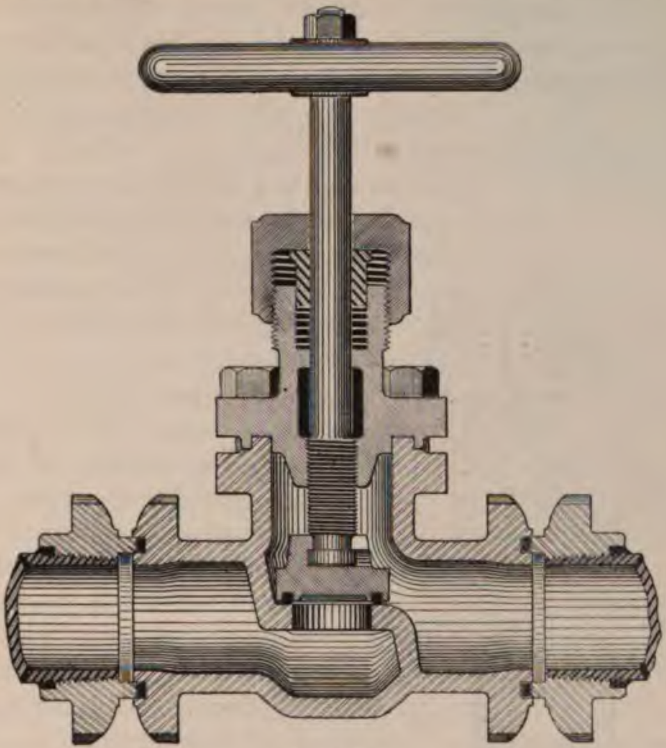


Fig. 37.

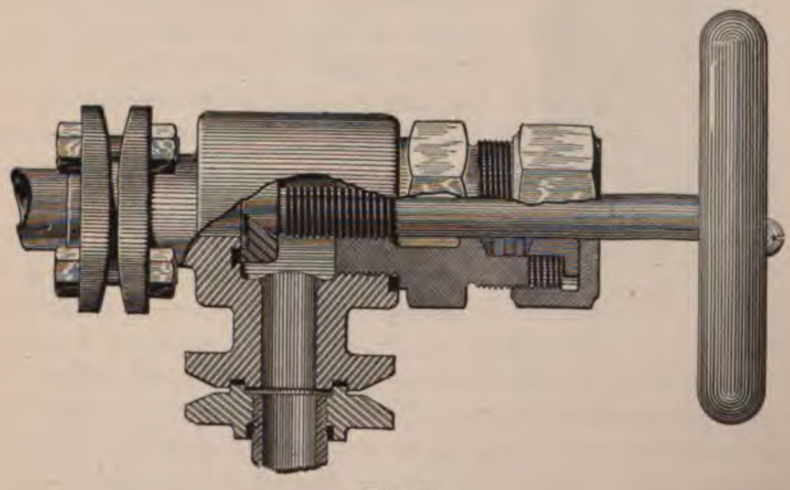


Fig. 38

may be well, however, to caution the user on the importance of testing the gauges often enough to be sure they are accurate, as serious damages may result from a wrong indication of pressure.

## BRINE.

Brine is used in refrigeration as a medium for the transmission of heat from the point or object to be refrigerated, to the ammonia or other refrigerant, and accordingly may be found in plants in which the application is indirect.

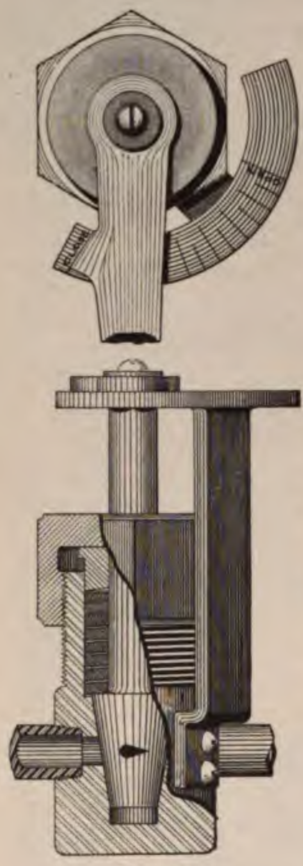


Fig. 39.

In the refrigerating practice of today, two kinds of brine are in use, chloride of calcium, and chloride of sodium (common salt). Either one is dissolved in water making a solution of the proper density; it is then pumped from the brine tank or cooler to the objects to be refrigerated, and returned by a system of pipes to be recooled and again circulated through the refrigerating system.

Chloride of calcium brine may be made of such density that its freezing point is—54° Fahr. (54° below zero) while chloride of sodium (salt) brine of maximum density or strength freezes at 0° Fahr. It will, therefore, be seen that for very low temperatures calcium brine should be used. For brine coolers in which the brine passes through the pipes, and the ammonia is evaporated on the outside with a temperature of a few degrees below zero, and the brine not in active circulation, salt brine would be frozen, bursting the pipes and causing a considerable loss. The calcium brine may be made of such density or strength as to make this impossible. It will, therefore, be evident that for use in connection with a brine cooler, the chloride of calcium brine is necessarily the choice It also has no corroding effect on pipes, pumps or other connections, and while the cost is somewhat more than that of salt, the general advantages are decidedly in its favor.

For the brine tank and coil system of refrigeration salt brine may be safely used, and is largely used at the present time. The evaporation of the ammonia, being within the pipes, can only effect the freezing of a small portion on the outer surface, and without damage to the plant. As its temperature may be reduced to zero, or even below (if circulation be maintained) it is effective for practical purposes wherein the temperature required is not below that point. The proper density, or strength of brine, either calcium or salt is determined by the temperature to which it is necessary to be reduced, and the tables on pages 79 and 80 will be found valuable in determining the proper strength for different requirements. It should be remembered, however, that a difference of from 5° to 10° Fahr. exists between the temperature of the brine and that of the evaporating ammonia, and that while the strength of the brine may appear ample for the temperature at which it is carried, the lower temperature of the evaporating ammonia may cause it to solidify within or upon the surface of the evaporator, thus causing it to separate, or freeze, and act as an insulator and prevent the transmission of heat through the surface. It is, therefore, necessary in examining into the strength of the brine, to consider it with reference to the evaporating pressure of the ammonia as well as its own temperature.

In the last column of the tables is given the gauge pressure, corresponding to the freezing point of the brine of different strengths.

The usual and proper instrument for determining the strength of brine is the Beaumè scale, for chloride of calcium brine. A weighted glass tube and bulb (Fig. 40) is graduated 0 to 100, the former being its floating point in water and the latter the floating point in a saturated solution of salt brine. By comparison of the two in the table of calcium brine it will be observed that the ratio of the two scales are as 1 to 4 which makes it possible to obtain one from the other.

In using the scales it is customary to draw a sample of the brine in a glass test tube, raising its temperature to approximately 60° Fahr. and insert the scale; it will then float at the point on its scale corresponding with its strength.

**Brine Systems.** In the use of the foregoing tables for calcium or salt brine, allowance should be made for the difference in the grades obtained. The quantity required per gallon, or cubic foot of brine, will vary accordingly. The average quantity required however, should nearly correspond with the tables.

In making brine it is well to fit up a box with a perforated false bottom, or, a more readily obtained and equally effective mixer may be made by taking a tight barrel or hogshead, into which is fitted a false bottom four to six inches above the bottom head, and which is bored with one-half inch holes. Over the false bottom lay a piece of coarse canvas or sack to prevent the salt falling through. A water connection is made in the side of the barrel near the bottom, between the bottom head and the false bottom, and a controlling valve placed nearby to regulate the amount of water passing through. An overflow connection is made near the top of the cask, with its end so placed that the brine will flow into the tank, and a wire screen placed across its end inside the cask with a liberal space between it, and the opening, to allow of cleaning. See Fig. 41. The cask or barrel is now filled with the calcium or salt, which dissolves and overflows into the brine tank.

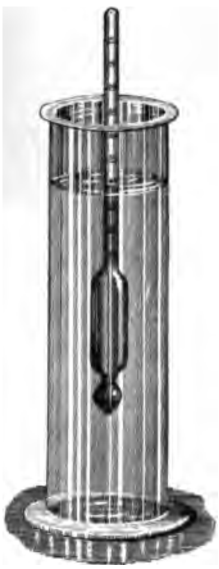


Fig. 40

A test tube and Beaumè scale, or salometer, should be kept at hand, and frequent tests made; the strength may be regulated by admitting the water more or less rapidly. After the first charge it is well to allow the mixer to remain in position for future requirements. A connection should be made from the return brine line from the refrigerating system to the cask, with a controlling valve by the use of which the strength or density of the brine may be increased without adding to the quantity, keeping the cask full of the calcium or salt, and allowing a portion of the return flow of brine to pass through the cask, dissolving the contents and flowing into the tank.

Calcium is usually obtained in sheet-iron drums, holding about 600 pounds each; it is in the shape of a solid cake within the drum. It is advisable to roll these onto the floor or top of tank in which the brine is to be made and pounded with a sledge hammer before removing the iron casing, this process breaking it up into small pieces without its flying about the room. After breaking it up the shell may be taken off and the contents shoveled into the mixer.

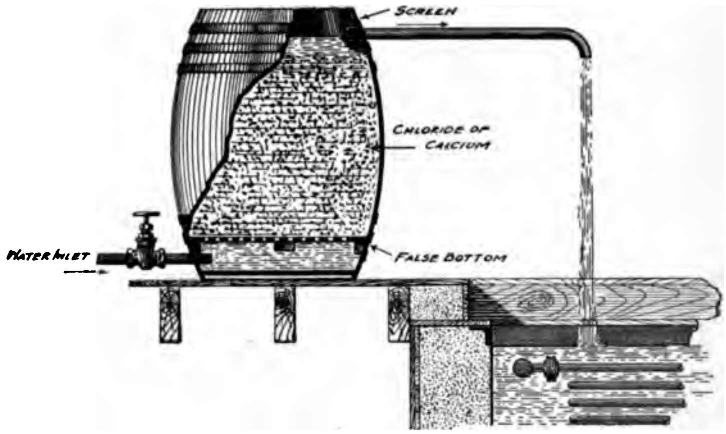



Fig. 41.

It is also sold and shipped in liquid form, in tank cars, generally in a concentrated form (on account of freight charges) and diluted to the proper point upon being put into the plant. Where proper railroad facilities exist, this is probably the most desirable way of obtaining the calcium.

Salt is sold and may be obtained in a number of forms. The usual shape for brine is the bulk, or in sacks of about 200 pounds each. Where it is possible to handle salt in bulk, direct from the car to the tank, this is most generally used on account of the price, being about $1.00 per ton less than if sacked. If it is necessary for it to be carted or stored before using, the sack form is preferable. The coarser grades of salt are used for this purpose, No. 2 Mine being the grade commonly used. The finer salts are higher in price, without a corresponding increase in strength of the brine formed.

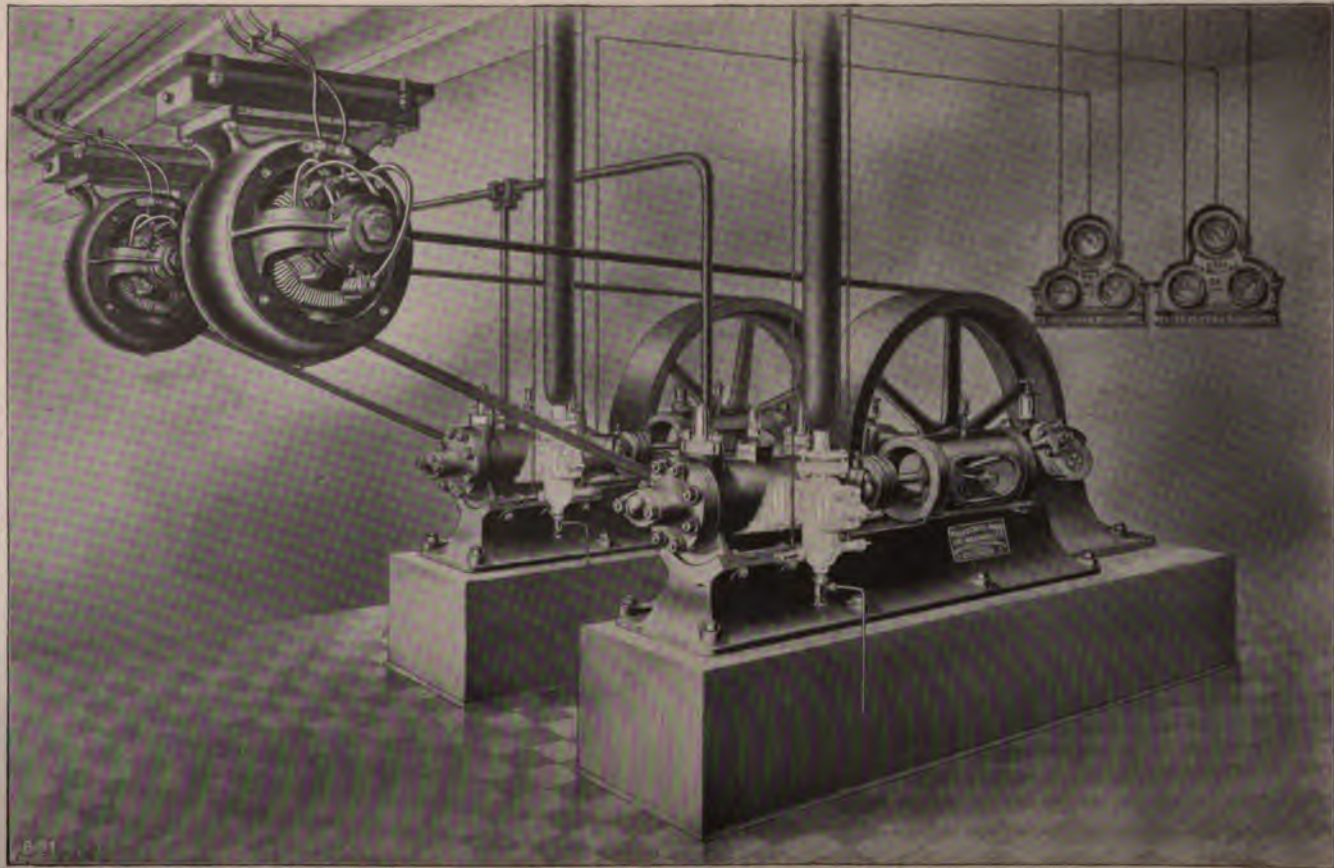
The proper density or strength of the brine must be determined for various temperatures. As a rule its freezing point should be equal to, or slightly below, the temperature of the evaporating ammonia, rather than the temperature of the coldest brine, as is common. Referring to the table of salt brine solution, page 80; if we wish to carry a temperature of 10° Fahr. in the outgoing brine, it is necessary that the temperature of the evaporating ammonia be from 5° to 10° degrees below that point, in order that the transfer of heat from the brine to the ammonia will be rapid enough to be effective, which would mean that the ammonia would be evaporating at a temperature of practically 0° Fahr. To prevent the brine freezing against the walls of the evaporator its strength or density should be made to correspond with this, or from 95° to 100° on the salometer. This should be cared for more especially in connection with plants using the brine cooler, in which the brine is within the coil, than in the brine tank system in which the ammonia is inside the pipe and the brine outside; here the only danger or loss would be in efficiency.

In examining into the causes of failure in a plant to perform its usual or rated capacity, it is advisable, unless there is every evidence that the trouble is elsewhere, to make an examination of the brine and determine that its strength and condition is suited to the duty to be performed.

## DIRECT EXPANSION.

As its name would imply, this system of refrigeration is one in which the refrigerant is expanded or evaporated in direct contact with the duty to be performed, without an intermediate agent for the transfer of the heat. Its application admits of quite a variety of apparatus to meet the requirements of refrigerating practice, the most general of which is the expansion within a pipe system placed in a room to be refrigerated, or within or between a series of pipes over or within which the substance to be refrigerated is passed.

While the former system admits of a variety of arrangements of the pipes within the room or chamber to be refrigerated, it is confined to the simple principle, however, of the evaporation of the refrigerant within the pipes, by the transfer of heat through the



**NORTHERN MOTORS OPERATING KROESCHELL BROS.' CARBONIC ANHYDRIDE ICE MACHINES**

In Refrigerating Plant of F. Newhall & Sons, Chicago.

walls of the pipe, thereby reducing the temperature in the room or chamber to the desired point, and for certain purposes is a very satisfactory means of producing the desired results. This is principally true with large rooms in which the temperature and duty to be performed is constant, such as a brewery, packing house, and cold-storage rooms. For rooms requiring an unusually low temperature, as freezers of fish and poultry, direct expansion is desirable, because it is possible to more nearly reach the temperature of

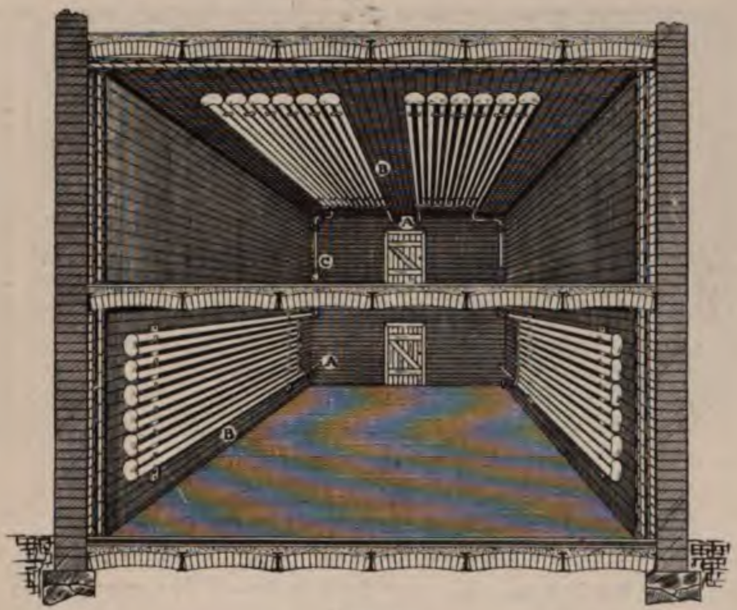


Fig. 42.

the refrigerant direct, than with an intermediate agent, as brine; this is due to the fact that there must necessarily be a difference of from 5° to 10° between the temperatures.

Fig. 42 illustrates a direct expansion construction in which the liquid anhydrous ammonia is expanded by the valve or cock A into the coil or system of pipes B and the gas returning to the compressor through the pipe C.

Fig. 43 represents a fish-freezing room on either side of which is arranged a series of pipe shelves, through which the ammonia is evaporated. The fish are laid on tin trays and placed on the pipe shelves until the room is filled. It is then closed, the ammonia turned on and left until the freezing has been accomplished.

It is apparent from the arrangement of the coils being both above and below the trays holding the fish, and close together, that the effect must be very rapid.

In the cooling of beer or other liquids, two forms of apparatus are used: one (the most common), being a series of a 2-inch pipe with return bends, stands, etc., over which the liquid to be cooled is flowed

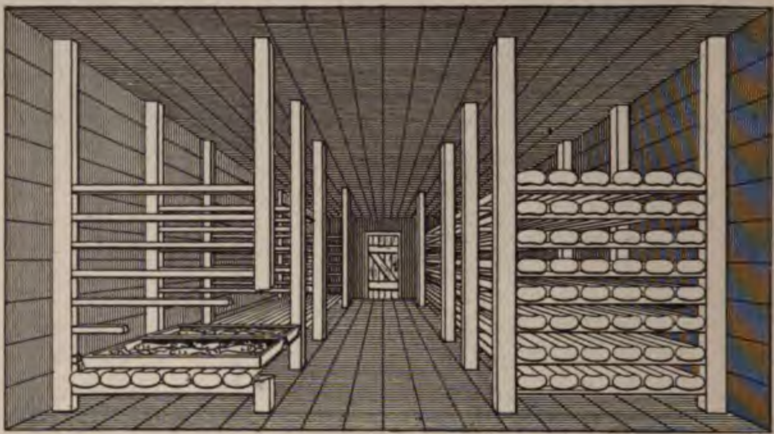


Fig. 43.

and within which the ammonia is evaporated, the product being accumulated in an iron pan or other receptacle in which the cooling pipes are placed. In brewery practice it is customary to provide a double series of coils, one above the other, cold water being circulated through the upper section, and the ammonia through the lower, the effect of which is first to remove the heat from the wort as far as possible by the use of water, and the remainder of the cooling being accomplished by the evaporation of the ammonia. This apparatus is called the Baudelot Cooler and is illustrated in Fig. 44.

Fig. 45 represents a section of a double-pipe cooler for water or other liquids and is similar to the form of double-pipe condenser or cooler already described. It varies only in the construction of the inner tube which is corrugated to prevent bursting by freezing, which becomes possible when used to cool a congealable liquid. In the operation of this type of cooler, when used as an evaporator or direct expansion cooler, it is usual to reverse the two currents, by feeding or expanding the ammonia into the bottom of the coil the gas issuing from the top, while the liquid to be acted upon enters at the top of the coil and issues from the bottom. This type of cooler is largely used in cooling carbonated ale, as it must be kept from the atmosphere, and for cooling drinking water in circulating systems now installed in hotels, office buildings and department stores.

**Purging and Pumping out Connection.** A common cause of failure to operate properly and effectively is the introduction of some foreign substance into the system. This will be readily understood and appreciated by engineers and those familiar with the requirements of a steam boiler. Clean surfaces on the shell or tubes are necessary for the maximum evaporation of water, or the transfer of heat through the walls of pipe or other forms of heat-transmitting surface. The most common difficulty encountered in a refrigerating plant is oil, either in its natural condition, or saponified by contact with the ammonia, water or brine. It enters the system in many ways: through leakage, condensation in blowing out the coils or system, foreign gas arising from decomposition of the ammonia through excessive heat and pressure, or the mingling of air which may enter the system through pumping out below atmospheric pressure or the air may have remained in the system from the time of charging, never having been fully removed. It is also probable, though hard to determine with certainty owing to the various conditions surrounding the operation of plants, that impurities are introduced with the ammonia, either as a liquid, gas or air which afterwards becomes impossible to condense.

The oil in a system forms a covering or coating on the evaporating surface which acts as an insulation and prevents the ready transfer of heat through the walls of the evaporator. The presence of water or brine causes an absorption of a portion of the ammonia into the water or brine, forming aqua ammonia which raises the boiling point of the ammonia and causes material loss in the duty. Air or other non-condensable gas in the system, excludes an equal volume of the ammonia gas, thereby reducing the available condensing surface in that proportion.

For the purpose of cleaning the system and removing the different impurities which may appear, purge and blow-off valves and connections are provided. One of these is placed at or near the bottom of the oil interceptor, which is located between the

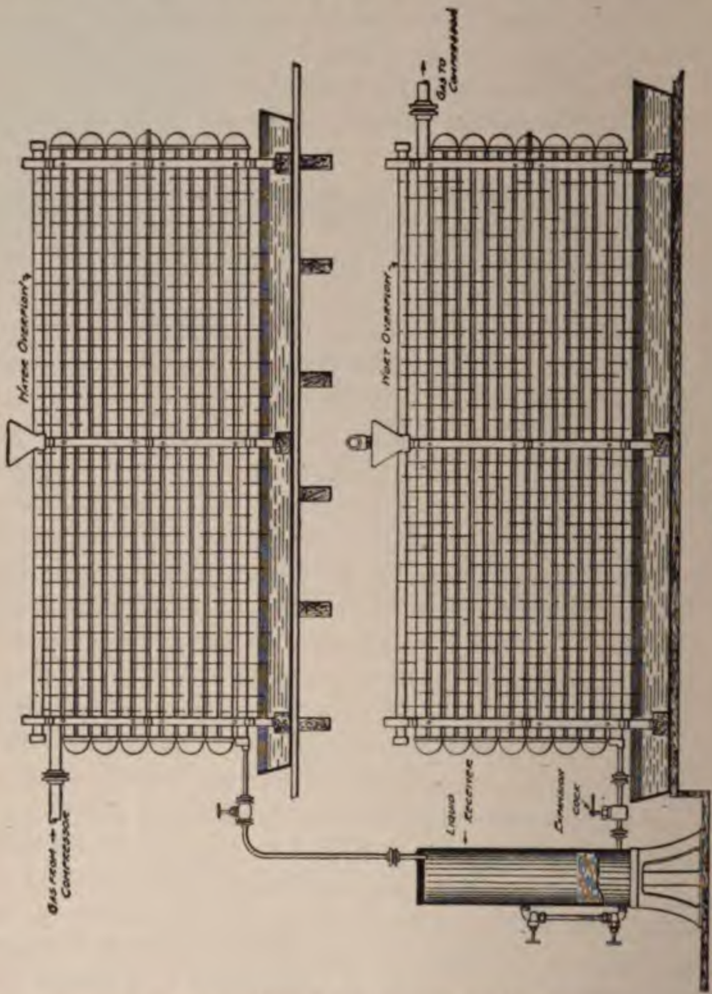


Fig. 44.

compressors and the condenser; it is used to draw off the oil used as a lubricant in the compressor and precipitated to the bottom. This oil should not be allowed to accumulate to any great extent as it may be carried forward to the condenser by the current of the gas.

If the liquid ammonia receiver be placed in a vertical position it is customary to place a purge valve in the bottom for drawing off oil or other impurities. The supply of liquid to the evaporator being taken off at a short distance above the bottom say 4 to 6 inches.

The next point for the removal of impurities is at the bottom of the brine cooler, or lower manifold of the coil system in a brine-tank refrigerator. These may be tried as often as necessary to determine the state of cleanliness of the system. If the system is charged with any of the common impurities, they should be blown out and the system cleansed at the earliest possible moment, as they cause a decided loss.

Air or foreign gases accumulate in the condenser because the constant pumping out of the evaporating system tends to remove them from that part of the system to the condenser. This point, therefore, is the most natural place for their removal. For this purpose it is customary on the best condensers to place a header or manifold at the top at one end, and connect each of the sections or banks with a valved opening. A valve is also placed at each end of the header, and a connection from one end of this header made to the return gas line between the evaporator and the compressors. By closing the stop valves on the gas inlet and liquid outlet of any one of the sections and opening the purge or pumping-out line into the gas line to the compressors, the section or bank may be emptied of its contents for repairs or examination and then connected up and put into service without shutting down the plant, or a material loss of ammonia. For purging of air or gas, the valve should be closed between this header and the machine, and the valve on the opposite end opened to the atmosphere, the valves on each section opened slightly in turn while the foreign gases are expelled. This process should not be used while the compressor is in operation, as the discharge of the ammonia into the condenser would keep the gas churned to the extent that it would become impossible to remove the foul gases, without removing a considerable portion of the ammonia also.

For this reason it is customary before blowing off the condenser to stop the compressor and allow the water to flow over the condenser until it is thoroughly cooled. Sufficient time should

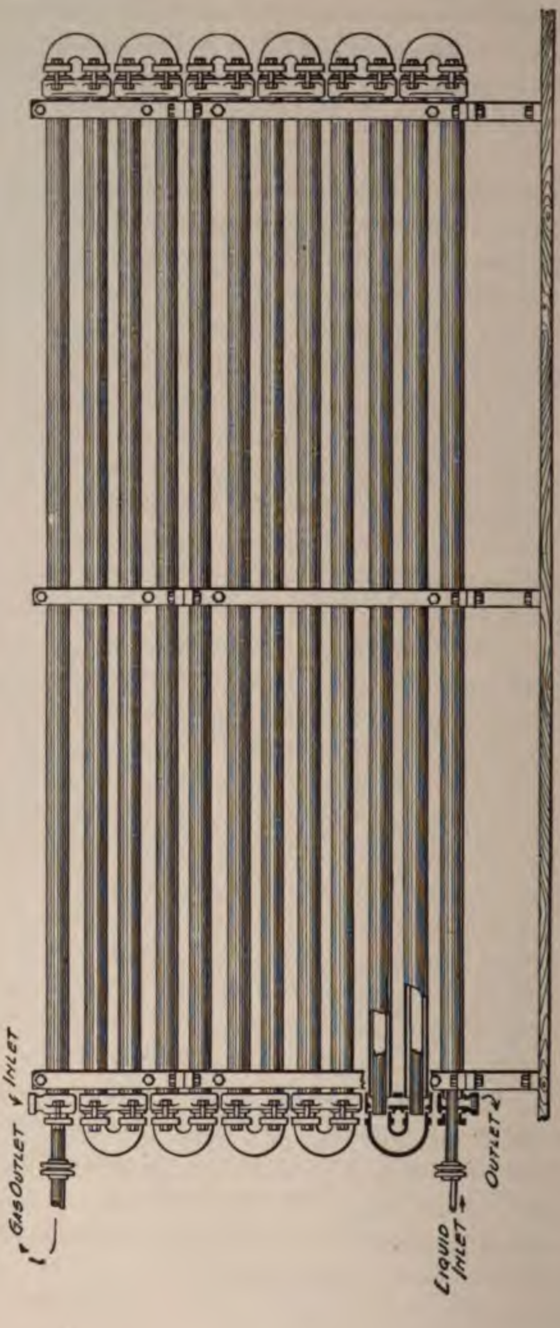



Fig. 45.

elapse for the ammonia to liquefy and settle towards the bottom, while the air and lighter gases rise to the top, at which point they may be blown out through the purge valve to the atmosphere. If doubt exists as to whether ammonia or impurities are being blown out attach a piece of hose to the end of the purge valve and immerse its other end in a pail of water. If it is air, bubbles will rise to the surface, while if it is ammonia, it will be absorbed into the water; the mingling of the ammonia with the water will cause a crackling sound, and the temperature of the water will increase owing to the chemical action.

## TESTING AND CHARGING.

Having described the different parts of the refrigerating plant and their relations to one another, let us consider the process of testing and charging, or introducing the ammonia into the system. After the connections are made between the different parts, whether the system is brine or direct expansion, it is necessary to introduce air pressure into it to determine the state of the joints. This may be done in sections or altogether. It is customary, however, to put a higher pressure on the compression side of the plant than on the evaporator owing to the difference in the pressure carried in operation. Adjacent to each compressor is placed a main stop valve, on both the inlet and outlet sides, while on either side of these it is customary to place a by-pass or purge valve.

Before starting the compressor, the main stop valve or valves (if there be two) on the inlet or evaporating side of the compressor, is closed, the small valve between the compressor and the main stop valve opened, and all of the other valves on the system opened except those to the atmosphere. The compressor may then be started slowly, air being taken in through the small by-pass valves and compressed into the entire system. It is well to raise a few pounds pressure on the entire system, before admitting water into the compressor water jackets or other parts of the system, because if a joint were improperly made up, it would be possible for the water to enter the compressors, or coils of the condenser or evaporator, and serious damage or loss of efficiency in the plant occur which it might be impossible to locate afterwards. While if pressure exists within the system when the water is admitted, its entrance into the coils or system is impossible while the pressure exists, and the leak is at once visible, and may be remedied before proceeding farther.

In starting the test it is also well to try the two pressure gauges and see that they agree as to graduation, as it has occurred that owing to a leakage between the discharge pipe and the high pressure gauge, an enormous pressure has been pumped into the system causing it to explode, resulting in loss of life and property. If, however, the pressures are found to be equal on the two gauges it is safe to assume that they are recording properly and their connections are tight. After these preliminaries it is safe to put an air pressure of 300 pounds on the compression side of the plant, care being taken to operate the compressor slowly, not raising the temperature of the compressed air too much, as with the utmost care in making up joints and in selecting material, certain weaknesses may exist, and under such high pressure it is well to proceed with caution.

After the desired pressure has been reached, the entire system should be gone over repeatedly until it is absolutely certain that it is tight. Parts which can be covered with water, such as a submerged form of condenser or brine tank with evaporating coils, should be so covered that the entire surface may be gone over at once and with almost absolute certainty. The slightest leakage will cause air bubbles to ascend to the surface; they may be traced by allowing the water to flow from the tank while the air pressure is still on the coils or system, watching the points where it stops and marking them, to be taken up or repaired when empty. For parts which cannot be covered with water, it is customary to apply with a brush a lather of such consistency that it will not run off too readily; upon coming in contact with a leak, soap bubbles are formed, and by tracing to the starting point the leak may be located. After the compression system has been subjected to a pressure of 300 pounds and found to be tight, the air may be admitted through the liquid ammonia pipe to the evaporating side of the plant, care being taken that the pressure does not rise above the limit of the gauge which as previously stated is usually 120 pounds and the same process of testing as applied to the opposite side of the plant gone over.

Many engineers require the vacuum test as well as the foregoing, and although if the former is gone over thoroughly, there can be little chance of leakage afterwards, it is better to be over-exacting than otherwise in the matter of testing and preparation of the plant, thus preventing the possibility of leaks that may prove disastrous. Open the main stop valves on the inlet line and close the main valves above the compressor on the discharge line, closing the by-pass valves in the suction line, and opening those in the discharge line between the main stop valve and the compressor. Have all the other valves on the system open as before for testing. Starting the compressor draws in the air filling the system through the compressor and discharging it at the small valve left open. Assuming the system to be tight, continuing the operation will finally exhaust the air (or nearly so), when the small valves should be closed and the pressure gauges watched to determine whether or not leakage exists.

Assuming that the system and apparatus is tight in every particular and that it is otherwise ready to be placed in operation, we are now ready to charge the ammonia into the plant.

If the air has been exhausted from the system in testing, this usual step need not be taken before charging, and it is only necessary to put the machine in proper condition to resume the pumping of the gas, and attach a cylinder of ammonia to the charging valve to enable the refrigeration to be commenced. The main stop valves above the compressor which were closed in expelling the air should now be opened and by-pass and other valves to the atmosphere closed. Close the outlet valve from the ammonia receiver and start the machine slowly, at the same time opening the feed valve between the drum of ammonia and evaporator. The anhydrous liquid ammonia will flow into the evaporator through the regular supply pipe, the gas resulting from evaporation being taken up by the compressors and discharged into the condenser and finally settling down into the receiver, when a sufficient quantity has been introduced to form a supply there. Upon closing the valves between the drum from which the supply is being drawn, and opening the outlet valve from the receiver, the process of refrigeration by the compression system is regularly in operation.

## OPERATION AND MANAGEMENT OF THE PLANT.

Assuming that the plant has been properly erected, tested, and charged with ammonia of a good quality, and (if a brine system) with brine of proper strength or density, as already explained, it only remains to keep the system or plant in that condition. As all forms of mechanism are liable to disarrangement and deterioration from various causes, repairs and corrections from time to time must be made to keep them in good condition. Let us now consider the most important points requiring attention.

It is absolutely necessary for the good working of any type of plant or apparatus that it be kept clean. As a steam boiler must be clean to obtain the full benefit of the fuel consumed, so must the surfaces of the condenser and evaporator be clean to obtain the proper results from the condensing water and evaporation of the ammonia or other refrigerant.

For satisfactory work the system should be purged of any foreign element present in the pipes, such as air, water, oil, or brine. Foreign matter is the most common among internal causes for loss of efficiency, and the valved openings which have been shown and described should be used for cleaning the system.

Oil is used as a lubricant in nearly if not quite all compressors, and the quantity should be the least amount that will lubricate the surfaces and prevent undue wear. This is considerably less than the average engineer is inclined to think necessary, and consequently a coating forms on the walls of the pipes or other surfaces of the condensing or evaporating systems, and a proportionate decrease in the duty obtained. It is also necessary that the oil be of such a nature that it is not saponified by contact with the ammonia. Such a change would choke or clog the pipes, coating their surfaces with a thick paste which causes a corresponding loss as the amount increases. The purge valve in the bottom of the oil interceptor may be opened slightly about once each week, and the oil discharged from the compressors drawn off into a pail or can, unless a blow-off reservoir is provided. After the gas with which it is charged has escaped, the oil should be practically the same as when fed into the compressors. If, however, the oil is not of the proper quality it will remain thick and pasty, or gummy, showing it to have been affected by the ammonia. Its use should not be continued.

By opening the purge valves, which are usually provided at the bottom manifold or header of the brine tank and the bottom head of the brine cooler, oil or water, if any be in that part of the system, may be drawn off. These valves, however, should not be opened unless there is some pressure in that part of the system, as air would be admitted if the pressure within the apparatus is below that of the atmosphere. Air may enter the system through a variety of causes and its presence is attended with higher condensing pressure and a falling off in the amount of work performed. For the removal of air from the apparatus a purge valve is placed at the highest point in the condenser or discharge pipe from the compressors near the condenser, which may be tried when the presence of air or foreign gases is suspected. This should be done after the compressor has been stopped. When the condenser has fully cooled and the gases separated, a small rubber hose or pipe may be carried into a pail of water and the purge valve or valves slightly opened. If air or other gases exist in the system bubbles will rise to the surface of the water so long as it is escaping, while, if ammonia is being blown off, it will be absorbed in the water and not rise to the surface.

To prevent the possibility of air getting into the system, the evaporating pressure should never be brought below that of the atmospheric, or 0° on the gauge, as at such times, with the least leakage at any point, it is sure to enter. Should it become necessary to reduce the pressure below that point, it is well first to tighten the compressor stuffing boxes and allow the pressure to remain below 0° only the shortest possible time as not only air may enter, but if it be the brine system and a leak exists, brine also will be drawn in.

From the foregoing it is evident that in order to obtain satisfactory results, the interior of the system must be kept clean by purging at the different points provided for this purpose; and it need only be added in this connection, that when the presence of oil or moisture becomes apparent in any quantity, the coils or other parts should be disconnected and blown out with steam until thoroughly clean and afterwards with air to make certain that condensation from the steam does not remain, after which the parts may again be connected and tested ready for operation.

If the plant be a brine system it is necessary that the brine be maintained at a proper strength or density to obtain satisfactory results, for if it becomes weakened it freezes on the surfaces of the pipes or evaporator, acting as an insulator and preventing the rapid transmission of heat through the walls.

Frequently the engineers or owners in looking about for the cause of a falling off in the capacity of a plant, overlook the fact that the strength of the brine is the sole difficulty, and the addition of salt or chloride of calcium is a remedy. Referring to the tables of brine solutions, there should be no difficulty in determining the proper strength of the brine for the different temperatures at which the plant may be operating; but as already stated, this should be made to correspond to the temperature of the evaporating ammonia rather than the temperature at which the brine may be handled.

It is of great importance to know at all times whether or not the gas taken into the compressors is fully discharged into the condenser, as the slightest loss at this point is certain to make itself felt in the operation of the plant. The compressor or valves seldom need be taken apart to determine their operation. The engineer should be able to discern the slightest change in temperature from the normal, when the compressors are working at their best, by placing the hand on the inlet and outlet pipes or the lower part of the compressors. Should the inlet pipe to one compressor be warmer than that to the other (of a pair), or the frost on the pipe from the evaporator reach nearer one compressor than the other, it is then certain that the one with the higher temperature, or from which the frost is farthest, is not working properly or doing as much duty as the other, and it is equally certain that some condition exists which prevents the complete filling and discharge of its contents; possibly it has more clearance or leaky valves.

The most common difficulties experienced with ammonia condensers are those of keeping the external surfaces clean and free from deposits, and preventing the accumulation of air or foreign gases within. Deposits on the surface are usually of two kinds, one which remains soft and may be washed off with a brush or wire scraper such as is used for cleaning castings in a foundry, the other a hard deposit which must be loosened with a hammer or scraper. It is hardly necessary to explain in detail the methods employed in cleaning the condenser as this is a matter that each engineer will be able to accomplish in his own way. It should not, however, be overlooked, and with a condensing pressure higher than ordinary, this should be the first point to be examined after the water supply.

Air, or foreign gases due to decomposition of the ammonia or other causes find their way into the condenser and make themselves manifest generally in a higher condensing pressure, or a falling off in the duty to be obtained from the plant. They should be blown off through the purge valve at the top of the condenser in the manner already described.

It is possible, through leakage of the coils or other parts of the apparatus, that the ammonia may become mixed with brine or water, thereby retarding its evaporation and interfering with the proper or usual operation of the plant. If this is suspected, a sample may be drawn off into a test glass through the charging valve or purge valve of the brine tank or ammonia receiver, and allowed to evaporate, in which case the water or brine will remain in the glass and the relative amount be determined. Through careful evaporation, and continued purging of the evaporator at intervals, this may in time be eliminated, and care should be taken to prevent future recurrence.

**Loss of ammonia** should be constantly guarded against. It is watchfulness which determines between a wasteful and an economical plant in this particular, and the engineer who allows the slightest smell of ammonia to exist about the plant is certain to be confronted with excessive ammonia bills; while he who is constantly on the alert and never rests until his plant is as free from the smell of ammonia as an ordinary engine room, will be referred to as the one who ran such and such a plant without addition of more ammonia for so many years.

The escape of ammonia into the atmosphere is readily detected; but where a leakage occurs in a submerged condenser, brine tank or brine cooler it is necessary to examine the surrounding liquid to determine whether or not it exists. For this purpose various agents are employed, and may be obtained of druggists or from the manufacturers of ammonia. Red Litmus paper when dipped into water or brine contaminated with ammonia will turn blue. Nessler's solution causes the affected water to turn yellow and brown, while Phenolphthalen causes a bright pink color with the slightest amount of ammonia present.

The stopping of a leakage of ammonia in the brine tank or cooler may be possible while the plant is in operation, by shutting off the coil in which it occurs, or, if the point is accessible a clamp and gasket may be put in place temporarily.

## PROPORTION BETWEEN THE PARTS OF A REFRIGERATING PLANT.

There is necessarily a certain ratio or proportion between the several parts of a refrigerating plant, as there is between the boiler, engine, and parts of a steam or power plant, in order to obtain the most economical results. It is first necessary that the evaporator be provided with heat-transmitting surface sufficient to conduct 284,000 B. T. U. from the brine to the ammonia, for each ton of refrigeration to be performed. Without going into a theoretical calculation of this amount, we shall state in both lineal feet of pipe and square feet of pipe surface the commercial sizes and amounts ordinarily in use.

The coil surface in a brine-tank system of refrigeration, should contain approximately 50 square feet of external pipe surface, to each ton in refrigerating capacity of the plant, when it is to be operated at a temperature of 15° Fahr. This is an ample allowance and will be found under general working conditions to give readily the required capacity. While tests have been made in which 40 square feet of pipe surface has been found sufficient for one ton of refrigeration, it will be safer to use the former amount, owing to the varied conditions under which a plant may be operated. This would amount in round figures to 150 linear feet of 1-inch pipe, 115 feet of 1¼-inch, 100 feet of 1½-inch, or 80 feet of 2-inch pipe.

The brine tank should contain from 40 to 60 cubic feet (depending on the amount of storage capacity desired) for each ton in capacity of the plant. The brine cooler should contain 12 square feet of external pipe surface for each ton, from which, in comparison with the amount required for the brine-tank system, the statements regarding the relative efficiency of the two methods of cooling brine may be more readily understood. This amount of surface would practically correspond to 35 linear feet of 1-inch pipe, 28 feet of $1\frac{1}{4}$-inch, 25 feet of $1\frac{1}{2}$-inch or 19 feet of 2-inch pipe. The shell of the cooler is made sufficiently large to contain only the number of coils necessary, there being no advantage in a larger shell.

The submerged type of ammonia condenser should contain approximately 35 square feet of external surface which nearly corresponds to 100 linear feet of 1-inch pipe, 80 feet of $1\frac{1}{4}$-inch, 70 feet of $1\frac{1}{2}$-inch and 56 feet of 2-inch pipe.

The atmospheric type of condenser should contain 30 square feet of external pipe surface which corresponds to 87 linear feet of 1-inch pipe, 69 feet of $1\frac{1}{4}$-inch, 60 feet of $1\frac{1}{2}$-inch and 48 feet of 2-inch pipe.

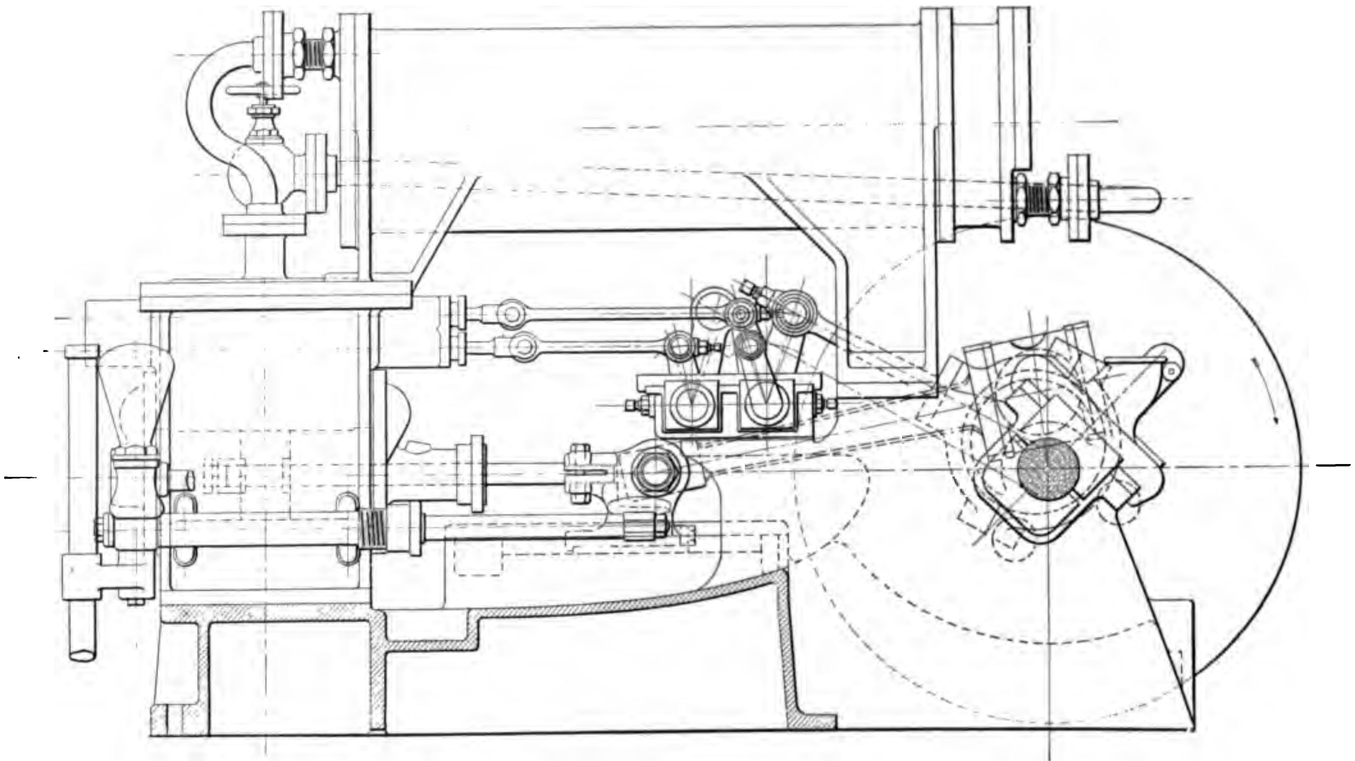
The double-pipe type of condenser, as usually rated, contains 7 square feet of external pipe surface for the water circulating pipe and about 10 square feet of internal surface of the outer pipe and corresponds to approximately 20 linear feet each of $1\frac{1}{4}$-inch and 2-inch sizes for each ton of refrigerating capacity.

The above quantities are based on a water supply of average temperature (60°) and quantity. In cases of a limited supply or higher temperature than ordinary, a greater amount should be used.

The ammonia compressor should be of such dimensions that it will take away the gas from the brine cooler, evaporating coils, or system, as rapidly as formed by the evaporation of the liquid ammonia, and unless the temperature at which the plant is to be operated be known, it is impossible to determine the volume of gas to be handled and the necessary sizes of the compressor.

As stated before, the unit of a refrigerating plant is usually expressed in tons of refrigeration equal to 284,000 B. T. U. Up to the present time, however, a standard temperature at which this duty shall be performed has never been established, and therefore the rating of a machine, evaporator, or condenser by tonnage is a merely nominal one and misleading to the purchaser, a range of as great as 50 per cent very often existing in the tenders for certain contracts. Upon the basis, however, of the average temperature required of the refrigerating apparatus that of 15° Fahr. is probably the mean; and at this temperature in the outgoing brine, it is necessary to take away from the evaporator nearly 7,000 cubic inches of gas per minute for each ton of refrigeration developed in twenty-four hours. This may be considered as a fair basis for the rating of the displacement of the compressor or compressors of the plant, unless a specific temperature is stated at which the plant is to operate. At 0° Fahr. it is necessary to calculate on approximately 9,000 cubic inches, while at 28° Fahr. about 5,000 will be the required amount.

For example, if we have two single acting compressors 12 inches diameter by 24 inches stroke operating at 70 revolutions per minute, we would have 113.09 (inches, area of 12-inch circle) × 24 (inches stroke) × 2 (number of compressors) × 70 (revolutions) ÷ 7,000 (cubic inches displacement required) = 54.28 (tons refrigeration per 24 hours of operation), while if the same machine is to be operated at or near a temperature of zero and we divide the product by 9,000 we have a capacity of 42.22 tons only in the same length of time. The above quantities are given as approximate only, but they have been deduced from the average results obtained from years of practice and will be found reliable under average conditions. It is to be hoped, however, that a standard will soon be adopted which will rate machines or plants by cubic inches displacement at a certain number of revolutions or a stated piston speed, and the cooling of a certain number of gallons of brine per minute through a certain range of temperature.



ALLEN DENSE AIR REFRIGERATING MACHINE.

**Thermometer Scales.**

| Fahr. | Cent. | Reau. | Fahr. | Cent. | Reau. | Fahr. | Cent. | Reau. |
|---|---|---|---|---|---|---|---|---|
| 212 | 100 | 80 | 120 | 48.9 | 39.1 | 30 | — 1.1 | — 0.9 |
| 210 | 98.9 | 79.1 | 118 | 47.8 | 38.2 | 28 | — 2.2 | — 1.8 |
| 208 | 97.8 | 78.2 | 116 | 46.7 | 37.3 | 26 | — 3.3 | — 2.7 |
| 206 | 96.7 | 77.3 | 114 | 45.6 | 36.4 | 24 | — 4.4 | — 3.6 |
| 204 | 95.6 | 76.4 | 112 | 44.4 | 35.6 | 22 | — 5.6 | — 4.4 |
| 202 | 94.4 | 75.6 | 110 | 43.3 | 34.7 | 20 | — 6.7 | — 5.3 |
| 200 | 93.3 | 74.7 | 108 | 42.2 | 33.8 | 18 | — 7.8 | — 6.2 |
| 198 | 92.2 | 73.8 | 106 | 41.1 | 32.9 | 16 | — 8.9 | — 7.1 |
| 196 | 91.1 | 72.9 | 104 | 40 | 32 | 14 | —10 | — 8 |
| 194 | 90 | 72 | 102 | 38.9 | 31.1 | 12 | —11.1 | — 8.9 |
| 192 | 88.9 | 71.1 | 100 | 37.8 | 30.2 | 10 | —12.2 | — 9.8 |
| 190 | 87.8 | 70.2 | 98 | 36.7 | 29.3 | 8 | —13.3 | —10.7 |
| 188 | 86.7 | 69.3 | 96 | 35.6 | 28.4 | 6 | —44.4 | —11.6 |
| 186 | 85.6 | 68.4 | 94 | 34.4 | 27.6 | 4 | —15.6 | —12.4 |
| 184 | 84.4 | 67.6 | 92 | 33.3 | 26.7 | 2 | —16.7 | —13.3 |
| 182 | 83.3 | 66.7 | 90 | 32.2 | 25.8 | 0 | —17.8 | —14.2 |
| 180 | 82.2 | 65.8 | 88 | 31.1 | 24.9 | — 2 | —18.9 | —15.1 |
| 178 | 81.1 | 64.9 | 86 | 30 | 24 | — 4 | —20 | —16 |
| 176 | 80 | 64 | 84 | 28.9 | 23.1 | — 6 | —21.1 | —16.9 |
| 174 | 78.9 | 63.1 | 82 | 27.8 | 22.2 | — 8 | —22.2 | —17.8 |
| 172 | 77.8 | 62.2 | 80 | 26.7 | 21.3 | —10 | —23.3 | —18.7 |
| 170 | 76.7 | 61.3 | 78 | 25.6 | 20.4 | —12 | —24.4 | —19.6 |
| 168 | 75.6 | 60.4 | 76 | 24.4 | 19.6 | —14 | —25.6 | —20.4 |
| 166 | 74.4 | 59.6 | 74 | 23.3 | 18.7 | —16 | —26.7 | —21.3 |
| 164 | 73.3 | 58.7 | 72 | 22.2 | 17.8 | —18 | —27.8 | —22.2 |
| 162 | 72.2 | 57.8 | 70 | 21.1 | 16.9 | —20 | —28.9 | —23.1 |
| 160 | 71.1 | 56.9 | 68 | 20 | 16 | —22 | —30 | —24 |
| 158 | 70 | 56 | 66 | 18.9 | 15.1 | —24 | —31.1 | —24.9 |
| 156 | 68.9 | 55.1 | 64 | 17.8 | 14.2 | —26 | —32.2 | —25.8 |
| 154 | 67.8 | 54.2 | 62 | 16.7 | 13.3 | —28 | —33.3 | —26.7 |
| 152 | 66.7 | 53.3 | 60 | 15.6 | 12.4 | —30 | —34.4 | —27.6 |
| 150 | 65.6 | 52.4 | 58 | 14.4 | 11.6 | —32 | —35.6 | —28.4 |
| 148 | 64.4 | 51.6 | 56 | 13.3 | 10.7 | —34 | —36.7 | —29.3 |
| 146 | 63.3 | 50.7 | 54 | 12.2 | 9.8 | —36 | —37.8 | —30.2 |
| 144 | 62.2 | 49.8 | 52 | 11.1 | 8.9 | —38 | —38.9 | —31.1 |
| 142 | 61.1 | 48.9 | 50 | 10 | 8 | —40 | —40 | —32 |
| 140 | 60 | 48 | 48 | 8.9 | 7.1 | —42 | —41.1 | —32.9 |
| 138 | 58.9 | 47.1 | 46 | 7.8 | 6.2 | —44 | —42.2 | —33.8 |
| 136 | 57.8 | 46.2 | 44 | 6.7 | 5.3 | —46 | —43.3 | —34.7 |
| 134 | 56.7 | 45.3 | 42 | 5.6 | 4.4 | —48 | —44.4 | —35.6 |
| 132 | 55.6 | 44.4 | 40 | 4.4 | 3.6 | —50 | —45.6 | —36.4 |
| 130 | 54.4 | 43.6 | 38 | 3.3 | 2.7 | —52 | —46.7 | —37.3 |
| 128 | 53.3 | 42.7 | 36 | 2.2 | 1.8 | —54 | —47.8 | —38.2 |
| 126 | 52.2 | 41.8 | 34 | 1.1 | 0.9 | —56 | —48.9 | —39.1 |
| 124 | 51.1 | 40.9 | 32 | 0 | 0 | —58 | —50 | —40 |
| 122 | 50 | 40 | | | | | | |

TEMPERATURE, PRESSURE, LATENT HEAT AND WEIGHT OF AMMONIA, OR PROPERTIES OF SATURATED AMMONIA.

| Temp. F. | Pressure | | Latent Heat | Volume in Cu. Ft. of 1 Lb. Vapor | Volume in Cu. Ft. of 1 Lb. Liquid | Weight of 1 Cu. Ft. Vapor |
|---|---|---|---|---|---|---|
| | Absolute | Gauge | | | | |
| —40 | 10.69 | —4.01 | 579.67 | 24.38 | .0234 | .0411 |
| —35 | 12.31 | —2.39 | 576 69 | 21.32 | .0236 | .0471 |
| —30 | 14.13 | — .57 | 573.69 | 18.69 | .0237 | .0535 |
| —25 | 16.17 | 1.47 | 570.68 | 16.44 | .0238 | .0609 |
| —20 | 18.45 | 3.75 | 567.67 | 14 48 | .024 | .069 |
| —15 | 20.99 | 6.29 | 564.64 | 12.81 | .0242 | .0775 |
| —10 | 23.77 | 9.07 | 561 61 | 11.36 | .0243 | .088 |
| — 5 | 27.57 | 12.87 | 558.56 | 9.89 | .0244 | .1011 |
| 0 | 30.37 | 15.67 | 555 5 | 9.14 | .0246 | .1094 |
| + 5 | 34.17 | 19.47 | 552.43 | 8.04 | .0247 | .1243 |
| 10 | 38.55 | 23.85 | 549.35 | 7.2 | .0249 | .1381 |
| 15 | 42.93 | 28.23 | 546.26 | 6.46 | .025 | .1547 |
| 20 | 47.95 | 33.25 | 543 15 | 5.82 | .0252 | .1721 |
| 25 | 53.43 | 38.73 | 540.03 | 5.24 | .0253 | .1908 |
| 30 | 59.41 | 44.71 | 536.92 | 4.73 | .0254 | .2111 |
| 35 | 65.93 | 51.23 | 533.78 | 4.28 | .0256 | .2336 |
| 40 | 73. | 58.3 | 530.63 | 3.88 | .0257 | .2577 |
| 45 | 80.66 | 65.96 | 527.47 | 3.53 | .026 | .2832 |
| 50 | 88.96 | 74.26 | 524.3 | 3.21 | .02601 | .3115 |
| 55 | 97.63 | 82.93 | 521.12 | 2.93 | .02603 | .3412 |
| 60 | 107.6 | 92.9 | 517 93 | 2.67 | .0265 | .3745 |
| 65 | 118.03 | 103.33 | 515.33 | 2.45 | .0266 | .4081 |
| 70 | 129.21 | 114.51 | 511.52 | 2.24 | .0268 | .4664 |
| 75 | 144.25 | 126 55 | 508.29 | 2.05 | .027 | .4978 |
| 80 | 154.11 | 139.41 | 504 66 | 1.89 | .0272 | .5291 |
| 85 | 167.86 | 153.16 | 501.81 | 1.74 | .0273 | .5747 |
| 90 | 182.8 | 168.1 | 498.11 | 1.61 | .0274 | .6211 |
| 95 | 198.37 | 183.67 | 495 29 | 1.48 | .0277 | .6756 |
| 100 | 215.14 | 200.44 | 491.5 | 1.36 | .0279 | .7353 |
| 105 | 232.98 | 218.28 | 488.72 | 1.29 | .0281 | .7862 |
| 110 | 251.97 | 237.27 | 485.42 | 1.2 | .0283 | .8451 |
| 115 | 272.14 | 257.44 | 482.41 | 1.12 | .0285 | .9042 |
| 120 | 293.49 | 278.79 | 478 79 | 1.04 | .0287 | .9738 |
| 125 | 316.16 | 301.46 | 475.45 | .97 | .0289 | 1.172 |
| 130 | 340.42 | 325.72 | 472.11 | .9 | .0291 | 1.2218 |
| 135 | 365.16 | 350.46 | 468.75 | .84 | .0293 | 1.3212 |
| 140 | 392.22 | 377.52 | 465.39 | .79 | .0295 | 1.4108 |
| 145 | 420.49 | 405.79 | 462.01 | .74 | .0297 | 1.4904 |
| 150 | 450.2 | 435.5 | 458.62 | .69 | .0299 | 1.5896 |

**Table of Calcium Brine Solution.**

| Deg. Baumé 60° F. | Deg. Salometer. 60° F. | Per Cent Calcium by Weight | Lbs. per Cu. Ft. Sol. | Lbs. per Gallon | Specific Gravity | Specific Heat | Freezing Point F. | Amm. Gauge Pressure |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 32 | 47.31 |
| 1 | 4 | .943 | 1.25 | 1/6 | 1.007 | .996 | 31.1 | 46.14 |
| 2 | 8 | 1.886 | 2.5 | 1/3 | 1.014 | .988 | 30.33 | 45.14 |
| 3 | 12 | 2.829 | 3.75 | 1/2 | 1.021 | .98 | 29.48 | 44.06 |
| 4 | 16 | 3.772 | 5 | 2/3 | 1.028 | .972 | 28.58 | 43 |
| 5 | 20 | 4.715 | 6.25 | 5/6 | 1.036 | .964 | 27.82 | 42.08 |
| 6 | 24 | 5.658 | 7.5 | 1 | 1.043 | .955 | 27.05 | 41.17 |
| 7 | 28 | 6.601 | 8.75 | 1 1/6 | 1.051 | .946 | 26.28 | 40.25 |
| 8 | 32 | 7.544 | 10 | 1 1/3 | 1.058 | .936 | 25.52 | 39.35 |
| 9 | 36 | 8.487 | 11 25 | 1 1/2 | 1.066 | .925 | 24.26 | 37.9 |
| 10 | 40 | 9.43 | 12.5 | 1 2/3 | 1.074 | .911 | 22.8 | 36.3 |
| 11 | 44 | 10.373 | 13.75 | 1 5/6 | 1.082 | .896 | 21.3 | 34.67 |
| 12 | 48 | 11 316 | 15 | 2 | 1.09 | .89 | 19.7 | 32.93 |
| 13 | 52 | 12.259 | 16.25 | 2 1/6 | 1.098 | .884 | 18.1 | 31.33 |
| 14 | 56 | 13 202 | 17.5 | 2 1/3 | 1.107 | .878 | 16.61 | 29.63 |
| 15 | 60 | 14.145 | 18.75 | 2 1/2 | 1.115 | .872 | 15.14 | 28.35 |
| 16 | 64 | 15.088 | 20 | 2 2/3 | 1.124 | .866 | 13.67 | 27.04 |
| 17 | 68 | 16.031 | 21.25 | 2 5/6 | 1.133 | .86 | 12.2 | 25.76 |
| 18 | 72 | 16.974 | 22.5 | 3 | 1.142 | .854 | 10 | 23.85 |
| 19 | 76 | 17.917 | 23.75 | 3 1/6 | 1.151 | .849 | 7.5 | 21.8 |
| 20 | 80 | 18.86 | 25 | 3 1/3 | 1.16 | .844 | 4.6 | 19.43 |
| 21 | 84 | 19.803 | 26.25 | 3 1/2 | 1.169 | .839 | 1.7 | 17.06 |
| 22 | 88 | 20.746 | 27.5 | 3 2/3 | 1.179 | .834 | — 1.4 | 14.7 |
| 23 | 92 | 21.689 | 28.75 | 3 5/6 | 1.188 | .825 | — 4.9 | 12.2 |
| 24 | 96 | 22.632 | 30 | 4 | 1.198 | .817 | — 8.6 | 9.96 |
| 25 | 100 | 23.575 | 31.25 | 4 1/6 | 1.208 | .808 | —11.6 | 8.19 |
| 26 | | 24.518 | 32.5 | 4 1/3 | 1.218 | .799 | —17.1 | 5.22 |
| 27 | | 25.461 | 33.75 | 4 1/2 | 1.229 | .79 | —21.8 | 2.94 |
| 28 | | 26.404 | 35 | 4 2/3 | 1.239 | .778 | —27. | .65 |
| 29 | | 27.347 | 36.25 | 4 5/6 | 1.25 | .769 | —32.6 | 1" Vac |
| 30 | | 28.29 | 37.5 | 5 | 1.261 | .757 | —39.2 | 8.5" " |
| 31 | | 29 233 | 38.75 | 5 1/6 | 1.272 | | —46.3 | 12 |
| 32 | | 30.176 | 40 | 5 1/3 | 1.283 | | —54.4 | 15 |
| 33 | | 31.119 | 41.25 | 5 1/2 | 1.295 | | —52.5 | 10 |
| 34 | | 32.062 | 42.5 | 5 2/3 | 1.306 | | —39.2 | 4 |
| 35 | | 33 | 43.75 | 5 5/6 | 1.318 | | —25.2 | 1.5 |

TABLE OF CHLORIDE OF SODIUM (SALT) BRINE.

| Degrees on Salom. | Percentage Salt by Weight | Pounds Salt per Cu. Ft. | Pounds Salt per Gallon | Specific Gravity | Specific Heat | Freezing Point F. | Ammonia Gauge Pressure |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 1 | 1 | 32 | 47.32 |
| 5 | 1.25 | .785 | .105 | 1.009 | .99 | 30.8 | 45.1 |
| 10 | 2.5 | 1.586 | .212 | 1.0181 | .98 | 28.6 | 43.03 |
| 15 | 3.75 | 2.401 | .321 | 1.0271 | .97 | 26.9 | 41 |
| 20 | 5 | 3.239 | .433 | 1.0362 | .96 | 25.2 | 38.96 |
| 25 | 6.25 | 4.099 | .548 | 1.0455 | .943 | 23.6 | 37.19 |
| 30 | 7.5 | 4.967 | .664 | 1.0547 | .926 | 22 | 35.44 |
| 35 | 8.75 | 5.834 | .78 | 1.064 | .909 | 20.4 | 33.69 |
| 40 | 10 | 6.709 | .897 | 1.0733 | .892 | 18.7 | 31.93 |
| 45 | 11.25 | 7.622 | 1.019 | 1.0828 | .883 | 17.1 | 30.33 |
| 50 | 12.5 | 8.542 | 1.142 | 1.0923 | .874 | 15.5 | 28.73 |
| 55 | 13.75 | 9.462 | 1.265 | 1.1018 | .864 | 13.9 | 27.24 |
| 60 | 15 | 10.389 | 1.389 | 1.1114 | .855 | 12.2 | 25.76 |
| 65 | 16.25 | 11.384 | 1.522 | 1.1213 | .848 | 10.7 | 24.46 |
| 70 | 17.5 | 12.387 | 1.656 | 1.1312 | .842 | 9.2 | 23.16 |
| 75 | 18.75 | 13.396 | 1.791 | 1.1411 | .835 | 7.7 | 21.82 |
| 80 | 20 | 14.421 | 1.928 | 1.1511 | .829 | 6.1 | 20.45 |
| 85 | 21.25 | 15.461 | 2.067 | 1.1614 | .818 | 4.6 | 19.16 |
| 90 | 22.5 | 16.508 | 2.207 | 1.1717 | .806 | 3.1 | 18.2 |
| 95 | 23.75 | 17.555 | 2.347 | 1.182 | .795 | 1.6 | 16.88 |
| 100 | 25 | 18.61 | 2.488 | 1.1923 | .783 | 0 | 15.67 |

## REVIEW QUESTIONS.

### PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for College, Civil Service, or Engineer's License. In some cases numerical answers are given as a further aid in this work.

## REVIEW QUESTIONS

ON THE SUBJECT OF

## MECHANISM.

---

1. An engine makes 280 revolutions per minute. If the stroke is 16 inches, what is the linear velocity of the crank pin in feet per second?

2. The pitch of a jack screw is $\frac{1}{4}$ inch. The length of the bar is 4 feet. What weight can be lifted if the force applied at the end of the bar is 148 pounds?

3. A worm of double thread meshes with a worm wheel having 64 teeth. How many revolutions per minute must the worm have to turn the wheel 2 times per minute?

4. A lever safety valve has a lever 30 inches long. The weight hung on the end weighs 24 pounds. If the valve is $4\frac{1}{2}$ inches from the fulcrum and has an area of $3\frac{1}{4}$ square inches, at what pressure per square inch will it blow off?

Neglect weight of valve, spindle and lever.

5. Define circular pitch. Diametral pitch.

6. If a gear has 20 teeth and it is 6 pitch, how far will the rack move in $2\frac{1}{2}$ revolutions of the gear?

7. Find the piston speed in feet per minute of an engine making 5.4 revolutions per second, the stroke being 18 inches.

8. Two gears mesh with each other. They are 8 pitch. If they have 40 teeth and 68 teeth, respectively, what are the diameters and how far apart should the centers of the shafts be placed?

9. The pitch circle of an annular gear is 36 inches in diameter. The spur gear meshing with it is 8 pitch and has 24 teeth. How many revolutions must the spur gear make to turn the annular gear 13 times per minute?

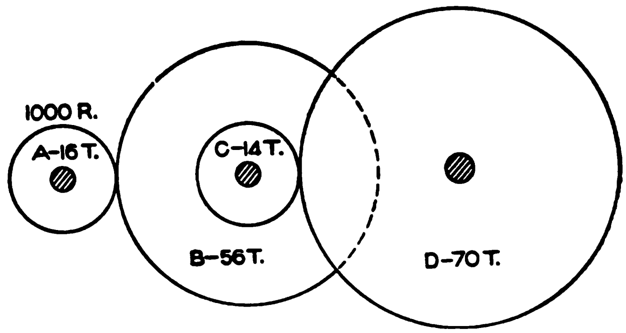
10. A lever is 26 inches long. A weight of 20 pounds is hung on one end. The distance of this weight from the fulcrum is 11 inches. What power will be necessary to raise the weight if the distance from the fulcrum to the power is 15 inches?

11. Describe the Whitworth quick-return motion.

12. A worm of single thread is in mesh with a worm wheel having 36 teeth. A crank of 16 inches radius is attached to the worm and a drum 10 inches in diameter is fastened to the worm wheel. How fast will the weight rise if the crank is turned 40 times per minute?

13. Suppose the press shown in Fig. 32, page 31, has a hand wheel 16 inches in diameter. The pitch $P = \frac{1}{4}$ inch and pitch $p = \frac{1}{8}$ inch. If 80,000 pounds are to be lifted what force must be applied to the hand wheel?

14. Describe some form of friction clutch.




15. In the train of gears shown, A is attached to the shaft of a motor and makes 1,000 revolutions per minute. How many revolutions per minute will gear D make?

16. If the linear velocity of the rim of a fly wheel is limited to a mile a minute, how many revolutions are allowable if the fly wheel is $7\frac{1}{2}$ feet in diameter?

17. A locomotive is running at the rate of 50 miles per hour. The drivers are 6 feet in diameter and the linear velocity of the crank pin is 24.44 feet per second. What is the length of stroke?

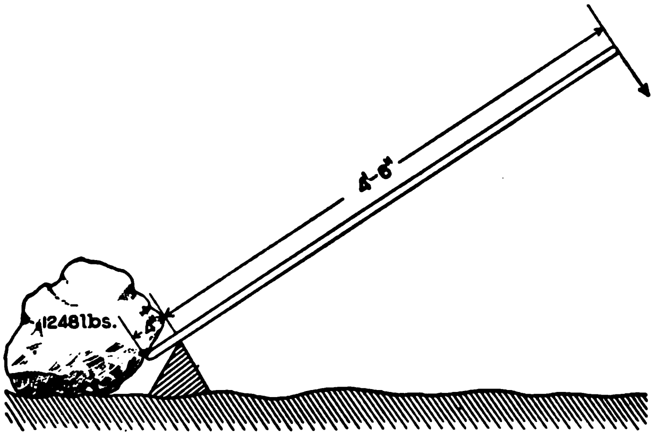
NOTE. The stroke=the diameter of crank-pin circle.

18. What is the pitch of a screw that advances 3 inches in 24 revolutions?

19. What weight can be raised by the device described in question 12 if the force applied to the crank is 110 pounds?

20. In the accompanying sketch, the large stone weighs 1,248 pounds. What force must be exerted at the end of the lever to move the stone?

**Note.** Assume that 40 per cent of the force necessary to lift the stone will move it.




21. If a gear has 48 teeth and the diameter of the pitch circle is 16 inches, what is the circular pitch? What is the diametral pitch?

22. A gear has 16 teeth and runs 800 revolutions per minute. How fast will a gear meshing with it run if it has 56 teeth?

23. The two sprocket wheels of a bicycle have 8 and 24 teeth, respectively. If the wheels are 28 inches in diameter, how many times must the pedals turn while the bicycle is going one mile?

24. In the above example, how many turns per minute must the pedals make if the bicycle moves at a velocity of a mile in 58 seconds?

25. What is pitch diameter?

26. If motion is desired along a shaft as well as at right angles to a shaft, what kind of cam must be used?

27. Two pulleys are connected by a leather belt. The driver is keyed to a shaft making 80 revolutions per minute, and is 34 inches in diameter. How many revolutions will the driven pulley make if it is 14 inches in diameter?

28. To what class does the lever of the lever safety valve belong?

## REVIEW QUESTIONS

ON THE SUBJECT OF

## THE STEAM ENGINE.

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1. What should be the rim weight of a cast iron fly-wheel which is 15 feet in diameter, if the engine is of the Corliss type, with an 18″ × 36″ cylinder, and runs at 90 revolutions per minute?

2. In what way does the action of steam in the turbine engine differ from the action of steam in the ordinary reciprocating engine?

3. What is the theoretical height of a simple pendulum governor which makes 65 revolutions per minute?

4. In what way did Newcomen improve the steam engine?

5. Explain the difference between the condensing and the noncondensing engine, and show why the condenser increases the power of the engine.

6. Describe two methods of overcoming the danger due to high rotative speed in the steam turbine.

7. What two principles did James Watt follow in his experiments on the steam engine?

8. What types of engines have no fly-wheel? Why have they no fly-wheel?

9. What should be the thickness of rim for a cast iron fly-wheel weighing 4,480 pounds; the face is 12 inches wide, and the diameter of the wheel 15 feet?

10. Name some of Watt's inventions and improvements in the steam engine.

11. What is meant by compound and triple expansion engines?

12. What is a Woolf engine? What is a tandem engine? A cross compound?

13. Explain with sketch the action of a sight-feed cylinder lubricator.

14. What is the function of a governor?

15. Why is not the power given out by an engine constant during a given time?

16. What are the relative advantages and disadvantages of turbine engines as compared with reciprocating engines?

17. What is the office of the fly-wheel?

18. How does the height of the governor affect its sensitiveness?

19. Why are lubricants used? Name the requisites of good lubricants.

20. Name the advantages of the vertical engine.

21. Describe the two kinds of governors.

22. In what two ways do governors vary the work done on the piston?

23. How are high-speed engines oiled?

24. Which class of engine needs the larger fly-wheel, and why, high speed or low speed?

25. Describe the direct-acting steam pump.

26. How does the action of the Buckeye engine governor in changing the amount of steam admitted per stroke differ from the action of the straight-line engine governor?

27. What are the advantages and the principal disadvantages of the Corliss engine?

28. Name the requisites for high-speed reciprocating engines.

29. Why do pumping engines usually have devices for economy?

30. Explain how the expansion of steam is obtained in each of the two types of steam turbine.

31. If the height of a simple pendulum governor is 8 inches, what is the equivalent height if a weight equal to 1½ times the weight of the balls is added?

32. Why is a vertical engine preferred to a horizontal engine for marine work?

33. Name, with the uses, the pumps used on ship board.

34. What kind of condenser is used in marine work? Why?

35. Why is a locomotive inefficient?

36. Describe the direct-acting duplex pump.

37. What happens if a locomotive is not correctly balanced?

38. Explain why the Cornish pumping engine was famous.

39. Are compound locomotive engines more economical than single expansion?

40. What danger arises from using the condensed steam from a surface condenser as feed water for the boiler?

## REVIEW QUESTIONS

ON THE SUBJECT OF

## REFRIGERATION.

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1. What is the principle upon which the modern method of refrigeration is based?

2. Why is it desirable to use a compressor?

3. A solution of chloride of sodium has a specific gravity of 1.10118. What is the freezing point in degrees Fahrenheit, and what is its density in degrees Salometer?

4. What do you consider the most important parts of a compressor?

5. Should the clearance of a compressor be small or great?

6. Why is ammonia so generally used in refrigeration?

7. What is the difference in the construction of a discharge valve and a suction valve?

8. Where should the oil separator be placed?

9. What is the difference between the direct-expansion system and the brine system?

10. What should be the displacement in the compressor for a seven-ton machine?

11. If a Fahrenheit thermometer in a room indicates a temperature of 38 degrees, what would be the reading of a Centigrade thermometer?

12. What temperature (Fahrenheit) would be indicated by a thermometer placed in an open vessel of liquid ammonia? What would be the temperature Reaumer?

13. Why is it important to have the spring of the discharge valve correctly adjusted?

14. What kind of valve is best adapted for regulating the flow of ammonia?

15. What are purge valves? Where are they placed?

16. Change 20 degrees Fahrenheit to degrees Reaumer.

17. For what purpose is brine used? Describe the two principal types of brine tanks.

18. What percentage of chloride of calcium by weight must be used to obtain a solution of 16 degrees Baumé? Temperature 60 degrees F.

19. Describe briefly the method of testing the plant.

20. Name the principal apparatus used in mechanical refrigeration.

21. What advantage does chloride of calcium have over chloride of sodium? Under what conditions should the calcium brine be used?

22. What is the specific gravity of a calcium brine solution at 60 degrees Fahr., if the hydrometer indicates 17 degrees Baumé?

23. Why must the brine be maintained at the proper density?

24. State briefly the function of the evaporation of the ammonia.

25. Why is the ammonia gas passed through a condenser?

26. How can the leakage of ammonia be detected in a submerged condenser?

27. Describe a good form of joint for ammonia piping.

28. State the advantage of the atmospheric type of condenser.

29. How many square feet of surface should be placed in a brine tank for a plant of 20 tons of refrigerating capacity? What should be the capacity (approximate) of the above tanks?

30. Describe briefly the construction of a double-pipe condenser.

31. What is the difference between the compression and the absorption systems?